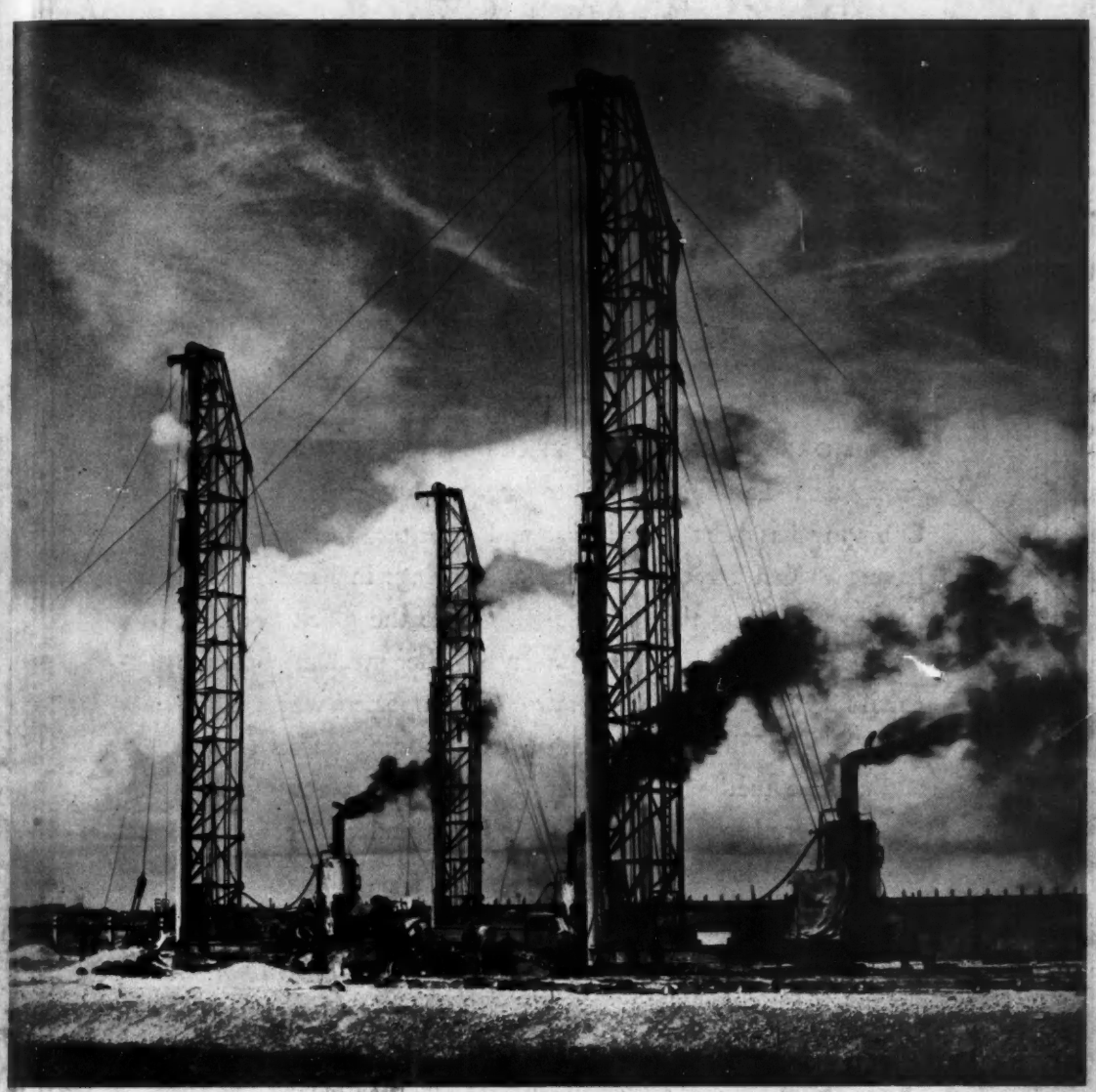
The Engineer

AUGUST 17, 1956 28 ESSEX ST., STRAND, LONDON, W.C.2 TWO SHILLINGS

UNIVERSITY OF MICHIGAN
SEP 5 1956
ENGINEERING LIBRARY



The VIBRO process is based on correct engineering principles and ensures the formation of piles of the precise length and size to suit the specified working loads.

The three Vibro plants shown above are forming 17" diameter piles varying from 60 to 70 feet in length, designed to carry working loads of 60 tons each.

BSP

VIBRO

CAST-IN-PLACE
REINFORCED
CONCRETE PILES

THE BRITISH STEEL PILING COMPANY LIMITED
10 HAYMARKET, LONDON S.W.1

HANDLING ECONOMY

FOR MORE THAN THIRTY YEARS Mitchells have supplied mechanical handling plant to the world's industries; the Company has been the pioneer and inventor of plants which have provided greater efficiency and savings in handling and site costs. Among these developments are the quick action of grabs closing in half the time taken by other mechanisms, with equal power; the non-skid control of transporters which eliminates all possibility of the transporter skidding on its tracks; and unique methods for guiding conveyor belts and ensuring that they are kept straight on their idlers under all conditions of service and loading.

Tipplers, wagon tippler hoists, ropeways, cableways, cranes and complete automatic wagon marshalling systems are other aspects of Mitchell enterprise.

MITCHELL

MITCHELL ENGINEERING LTD MITCHELL ROPEWAYS LTD

JOHN M HENDERSON LTD

ONE BEDFORD SQUARE LONDON WC1

THE ENGINEER

VOL. 202 No. 5247 AUGUST 17, 1956

CONTENTS

LEADING ARTICLES—
Motor Industry and Trade Unions ... 217
High-Speed Lightweight Rolling Stock in the United States 218

ARTICLES—
Boundary Lubrication 239
Cut-offs in Modern Hydraulic Diversion Works on Alluvial Rivers. No. II. (Illus.) 228
Engravings of 1874... 235
Further French Locomotive Experiences. No. II. (Illus.) 221
Great North Road Improvements ... 219
High Marnham Power Station. (Illus.) 240
Hydraulic Self-Aligning Seating. (Illus.) 232
Improvement Scheme for the River Lee Navigation 219
Impulse Tests on 275kV Super-Grid Transformer. (Illus.) 241
Lloyd's Shipbuilding Returns 219
Marine Radar Equipment. (Illus.) ... 239
Metal-Rectifier Welding Set 238
Opencast Coal Production 219
Producer Gas Trials. (Illus.) 238
Resonance Stress Testing. (Illus.) ... 224
Shipbuilding Orders for Abroad 219
Sound System for Colston Hall Organ Tuning. (Illus.) 241
Static in the Stars ? 230
7kW Induction Heater. (Illus.)... ... 240
100 Years Ago 218

CONTINENTAL SECTION—
CERN European Proton Synchrotron. (Illus.)... 243
Trials of Turbo-Charged Two-Stroke Marine Diesel Engine. (Illus.) ... 245

AMERICAN SECTION—
U.S. Earth Satellite Programme for the International Geophysical Year. (Illus.) 247
New Construction Programme of the Bureau of Reclamation 249

LETTERS AND LITERATURE 236

LETTERS TO THE EDITOR—
Cut-offs in Modern Hydraulic Diversion Works on Alluvial Rivers 236
Road Research 236
James Nasmyth, 1808–1890 236

LITERATURE 236

OBITUARY—
Sir William Paterson 220
Victor Edward Pullin 220

NEWS AND NOTES—
British Patent Specifications. (Illus.)... 251
Catalogues and Brochures 252
Forthcoming Engagements 252
Industrial and Labour Notes 242
Launches and Trial Trips 252
Personal and Business 250
Technical Reports 252

MOTOR INDUSTRY AND TRADE UNIONS

Last spring the Executive Council of the Confederation of Shipbuilding and Engineering Unions gave consideration to the question of redundancy and short-time working in the motor car industry and allied trades. A resolution was forwarded to Mr. Peter Thorneycroft, President of the Board of Trade, urging the Government to undertake an immediate fact-finding inquiry into the general position of the motor car industry, including design, capital investment, profits, and export organisation. Mr. Thorneycroft, in his reply, expressed the view that the industry consisted of a number of individual manufacturers who were in keen competition with each other and with overseas competitors, and that, in his opinion, individual and independent direction offered a better guarantee of success than a Government inquiry.

A document, originally prepared by the Confederation to substantiate the proposal for a fact-finding inquiry into the motor industry, was published early this month. It sets out to prove that such an inquiry might well have prevented the dismissal of workers and the consequent labour disputes in Coventry and Birmingham. This little pamphlet, "The Motor Vehicle Industry" (published by the Confederation of Shipbuilding and Engineering Unions, London, W.C.1), gives a fair and objective view of the causes leading to the setback which overtook the motor car industry last autumn and became so apparent in the opening months of this year. It traces the decline of sales in the home market to the Government's decision to impose new restrictions on hire purchase transactions, to the increased purchase tax, and to the general "credit squeeze" policy. The Confederation believes that there is still scope for considerable expansion in car ownership, and that an abolition of the above-mentioned "artificial restrictions" would help to stimulate home demand for new cars. Although the booklet stresses the importance of a healthy home market, it asserts the necessity not only of maintaining, but of increasing the present volume of exports and of regaining for this country's motor car industry its former position as the greatest motor car exporter of the world. Backed by well-compiled statistical material, it shows that the sharp setback in exports has taken more the form of a decline in the proportion of the growing world market served by Britain than of any appreciable fall in the number of cars sold abroad. The drop in exports is particularly noticeable in Scandinavia and Switzerland, that is, precisely in those markets which are generally regarded as reliable indicators of the competitive strength of the various national motor exporting industries. In both these areas competitive conditions exist, and the effect of artificial trade restrictions, including exchange and import controls and discriminating tariffs and preference clauses, is generally less pronounced than in other markets. Among the reasons why British car exports have failed to advance, particularly in Europe and on the American Continent, the document mentions "faults in design and manufacture, inferior after-sales service in foreign countries, and poor salesmanship." We, and several other technical papers, have discussed the question of car design, workmanship and after-sales service (we did so, for example, in our report on the Geneva Show in our issues of April 27 and May 4, 1956). There is therefore no need for us to stress the importance or the validity of these points. We should like to emphasise, however, that they are so well known, inside the motor industry as well as amongst the general public, that it is difficult to see what new facts a Government-sponsored "fact-finding" committee could find! If there are any deficiencies in design and workmanship, as, no doubt, there are and always will be, the individual motor manufacturers should be well aware of them, for no reputable firm could afford to ignore frequent complaints from customers and traders without making at least some effort to put matters right. Increased competition at home and abroad takes care that out-of-date designs disappear sooner or later.

The booklet is rather reluctant to advance any constructive ideas that might be advanced at the proposed inquiry. It only suggests that "Britain's competitive power in design, car performance, prices, after-sales service and salesmanship should be as effective as possible." It asserts that "in the past too many British industries have neglected to keep abreast of the rest of the world," and advocates that the "British motor industry should show itself ready to adopt the most up-to-date methods of production, including the use of transfer machines and other auto-

matic methods." Brave words indeed! But we cannot help feeling that, at least in the past, trade union leaders have been more concerned to devote their energies to wage claims than to recommendations for higher productive efficiency. It is therefore particularly pleasing to see a responsible body like the Executive Council of the C.S.E.U. publicly and forthrightly advocating automation, although it must be aware that tooling up for new models or the adoption of modern manufacturing methods are both likely to produce temporary redundancies.

HIGH-SPEED LIGHTWEIGHT ROLLING STOCK IN THE UNITED STATES

Writing of the lightweight "Aerotrain" which was on exhibition early in the present year at Grand Central Terminal, N.Y., Mr. Robert R. Young, chairman of the New York Central Railroad, is reported to have observed that "The economics of our entire passenger operations, terminal as well as over the road, must in some way be made to justify the putting of this train into volume production, with frequent model changes. In no other way can we reverse the direction of a dying business into a dynamically expanding one." Equally enthusiastic were the comments of Mr. Patrick B. McGinnis, president of the New York, New Haven and Hartford, who stated his belief that the "Aerotrain" may be the answer to the railroads' passenger problems. He added that the New Haven Railroad had ordered "three different prototypes of new, low center of gravity, lightweight trains." There were, wrote Mr. McGinnis, "two major reasons for the New Haven's enthusiasm over the new lightweight trains: First is the fact that by virtue of the design of the trains the New Haven will be able to offer to its patrons much faster and more comfortable service."

It is interesting to refer, in this connection, to observations on the operating expenses of high-speed lightweight trains contained in a paper by C. T. Ripley, communicated as long ago as 1939 to the American Society of Mechanical Engineers. Already in 1939 the low-priced private automobile and the construction of hard-surfaced roads had, with the development of aeroplane and road bus travel, brought about a serious decrease in railway passenger traffic. This, in turn, had led to a great amount of hard thinking on the part of the railway administrations, one line of inquiry being concerned with the scope for reducing weight of rolling stock without sacrifice either of safety or of comfort. Mr. Ripley's investigations showed that while for the conventional air-conditioned steel passenger coach seating fifty-eight passengers the weight per passenger was 2962 lb, this could be reduced to 1540 lb in the case of the lightweight stainless steel air-conditioned coach seating sixty-three passengers. The "Aerotrain" as exhibited in New York, consists of ten two-axled bus-bodies stated to be air-conditioned adaptations of the present body of the G.M.C. forty-passenger inter-city type highway coach. With ten of these coaches the total number of seated passengers is 400, among the amenities being provision for equipping each car with an aeroplane type stainless steel galley for the preparation of light meals.

The Engineer

100 Years Ago

(AUGUST 15, 1856)

"THE SUEZ CANAL"

"M. Ferdinand de Lesseps has been at Turin, and also at Genoa, on his way to Alexandria. His object has been to visit M. Paleocapa, the minister of public works, an engineer who gained great reputation by carrying out successfully the pier at Malamoco. The motive of this visit has not been to consult M. Paleocapa on the construction of the works of the Suez canal, but in order to overcome a greater difficulty—the opposition, namely, of the Sultan to the project; an opposition encouraged, it is said, by Lord Stratford de Radcliffe; and grounded on the fear that the transit of the East Indian, and Chinese commerce, by way of the Isthmus, will so greatly increase the wealth of the Viceroy, as to make him practically independent. The Sultan had put his veto on the convention concluded between the Canal Company and the Viceroy; this veto M. Ferdinand Lesseps wants to remove, and he resorts to M. Paleocapa, because he is aware that that gentleman stands very well with his Majesty Napoleon III, in consequence of a recent visit which he paid to Paris, on the subject of embanking the Rhone and the Loire. It is in order to induce M. Paleocapa to employ his influence with Louis Napoleon, in opposition to the Sultan's veto on the canal project, that M. Lesseps has paid his recent visit."

"A NEW PHASE IN IRON MAKING"

"In another page our readers will find a report of Mr. Bessemer's new discovery in the manufacture of iron, which, if it proves to be all that is represented (and at present there is little reason for doubt), promises completely to revolutionise the iron manufacture as at present conducted. All who are engaged in this department will, therefore, read this paper with more than ordinary interest. We understand our friend, Mr. Nasmyth, is entitled to *some* portion of the merit due to this discovery, and we are told that Mr. Bessemer is not unwilling to share it with that gentleman."

The ten coaches are coupled to a diesel-electric locomotive (General Motors class 0-4-2-0, serial number 21464, December, 1955) powered by a twelve-cylinder General Motors engine of 1200 h.p., the engine, the generator and the accessories on the locomotive being standard equipment. The axles on the leading four-wheeled truck are geared to traction motors, the single axle at the rear being an idler. Each coach weighs 16 tons, which compares with, say, 65 tons in the case of the normal American passenger coach. Conventional steel springing has been replaced, on the coaches of the "Aerotrain," by rubber bellows, it being claimed that "air suspension stabilises and cushions the ride, whether the car has only a few passengers or is fully loaded, and makes a major contribution to weight reduction." Auxiliary power is supplied by two General Motors 6-71 Detroit diesel engines which operate electric generators for train heating, lighting and air conditioning. The locomotive is fitted with dynamic braking and the maximum speed of the "Aerotrain" is 100 m.p.h., at which speed the fuel consumption is said to be at the rate of 1·3 gallons of fuel oil per mile.

It is interesting to compare the weight and the passenger carrying capacity of the coaches in the "Aerotrain" with the similar particulars relating to the latest lightweight main line passenger coaches on the Swiss Federal Railways. In the case of the "Aerotrain" coaches (each of which weighs 16 tons and carries forty passengers) 2·5 passengers are carried per ton of coach. In the case of the Swiss passenger coach (which has seats for seventy-two passengers) the weight is 27 tons, so that almost exactly 2·7 passengers are carried per ton. It is to be remembered that the Swiss coaches are carried on two four-wheeled trucks, have normal springing, ample seating room, specially good facilities for the rapid entrance and exit of passengers and are provided with the necessary toilet accommodation. They are not air conditioned. As for the conventional eighty-passenger long-distance air-conditioned American railroad coach weighing, say, 65 tons, 1·23 passengers are carried per ton. In the three examples mentioned the comparison—on the basis of weight per passenger—is as follows:—"Aerotrain" coach, 800 lb per passenger; Swiss light main line coach, 840 lb per passenger; conventional American passenger coach, 1625 lb per passenger. The bearing of these figures on the power required for hauling as well as on overhead maintenance and operating cost needs no stressing, though it will not be forgotten that only as a result of prolonged experience can it be possible to ascertain the position in relation to maintenance costs and performance in accidents. Difficult as are certainly the problems facing the railways, they present powerful inducements to enterprising and imaginative manufacturers of railway equipment. That "Difficulties are things which show what men are" is as true to-day as it was in the time of Epictetus, and contemplating the intensity of effort reflected by such examples as the "Aerotrain," "Train X," the "Talgo," and the "Jet Rocket" (lately announced as about to be introduced on the Rock Island), railway managements will be encouraged to look with renewed hope towards the future of their passenger carrying business.

A Seven Day Journal

Opencast Coal Production

AT the beginning of this week, the chairman of the Federation of Civil Engineering Contractors, Lieut.-Colonel T. McMillan, commented on various matters concerned with opencast coal production in this country. About the new ten-year programme he said that contractors could undoubtedly produce substantially more than the envisaged average output of 10,000,000 tons a year if the necessary sites could be made available. Prospecting must in any event, Colonel McMillan urged, be pushed ahead so that contracts could be let in such a way as to give contractors a reasonable chance of keeping the big excavators used for overburden removal continuously employed. Colonel McMillan went on to emphasise that the standard of restoration of sites after working was very high and that the acreage of farmland temporarily occupied for opencast mining at any one time was extremely small, amounting to about 30,000 acres out of a total of some 45,000,000 acres. On the question of plant, Colonel McMillan said that British contractors had always preferred to use British equipment wherever practicable, but for the heavy excavating machinery needed for opencast coal production, the major source of supply able to offer quick delivery in large quantities had been America, where these machines were in regular production. Moreover, such machines yielded a very high return in dollars, as 100 cubic yards capacity of imported plant, costing approximately £1,500,000, would produce during its working life at least 10,000,000 tons of coal, thus saving some £70,000,000, mainly in gold or dollars, on coal imports. The high mechanisation of opencast coal mining, he continued, enabled 9000 men to do the earth-moving of 500,000 pick and shovel workers, with a productivity four times as high as in the pits, and linked with increased efficiency had kept the cost of producing opencast coal virtually stable over the past four years, despite substantial increases in costs and wages generally. Maximum opencast coal production was essential, Colonel McMillan observed, and continuing investment must be made in the earth-moving machinery if the present efficiency was to be maintained. It was to be hoped, therefore, that all necessary dollar imports of earth-moving machinery would be sanctioned and, moreover, that the credit squeeze would not be allowed to interfere with the financing of these purchases.

Improvement Scheme for the River Lee Navigation

A SCHEME to improve the River Lee Navigation between Enfield Lock and its junctions with the River Thames, at a cost of £864,000, has been announced by Sir Reginald Kerr, general manager of the British Transport Commission's Waterways Division. It is the largest project yet to be announced in the Commission's £5,500,000 development plan for its principal inland waterways. The scheme, it is stated, will reduce by half the time taken by the large Lee craft in navigating the locks above Old Ford and will open up the whole section, Thames to Enfield (13½ miles), to the largest barges used by the carriers. It will provide "fully modern" standards of bank protection and dredging. Although the River Lee is navigable throughout its length, traffic is mainly concentrated on the heavily industrial section between the Thames and Enfield; in 1955 traffic on this 13½ mile section amounted to 2,433,000 tons, half of it being coal for the power stations at Hackney, Poplar and Brimsdown. The new scheme mainly comprises: bank protection, £470,000; bridge construction and replacement, £64,000; additional locks, £268,000; dredging craft, £58,000. Bank protection will involve 32,000ft of steel piling and 3300ft of mass concrete walling. Owing to the use of powered craft and successive dredging, much of the old stone walling now protecting the tow-path requires replacement. Steel piling, driven in front of the existing walls, will be used for all this work except on the highly congested and narrower reach between Limehouse and Three Mills, Bow, where mass concrete walling, which involves no restriction of the waterway, will be provided. The single locks at Tottenham and Stonebridge Locks, Tottenham, and at Pickett's Lock, Edmonton, are to be doubled, each new lock being large enough to take a 135-ton, 18ft-wide Lee barge. A similar new lock to be built at Ponders End, where the existing single lock is only 16ft 6in wide, will open this part of the waterway to the large Lee barges used by the lighterage companies. The doubling of Tottenham Lock will involve the construction of a new bridge under Ferry Lane. Also, Three Mills Lane Bridge, Bow, will be reconstructed to provide a wider waterway, increased head-room and a stronger superstructure. Finally, the fifteen wooden craft in the Lee fleet of dredging hoppers are to be replaced with modern steel hoppers, together with one additional craft to bring the hopper fleet up to a standard strength of twenty-eight steel barges.

Lloyd's Shipbuilding Returns

THE shipbuilding returns for the quarter ended June 30th have been published by Lloyd's Register of Shipping. Work in hand in Great Britain and Northern Ireland amounted to 334 steamships and motorships of 2,028,132 tons gross, a decrease of 232,817 tons compared with the previous quarter. Progress during the three months showed that 62 ships of 277,108 tons were commenced and that 76 ships of 306,053 tons were launched, while at 82 ships of 516,763 tons the total completed was the highest since 1921. The total of 74 ships of 464,905 tons for registration abroad is 263,636 tons less than in the previous quarter, and represents 22·9 per cent of the tonnage being built as compared with 40·4 per cent or 825,745 tons in September, 1950. Oil tankers totalled 62 ships of 833,301 tons, a decrease of 111,963 tons, compared with the previous quarter, and representing 41·1 per cent of the ships being built. The volume of orders outstanding at 2,116,962 tons represented an increase over the March quarter of 398,301 tons, and compare with 1,322,699 tons of a year earlier. Abroad, 1200 ships of 5,194,872 tons gross were under construction, an increase of 446,642 tons during the quarter, while the totals commenced, launched and completed were 379 ships of 1,608,934 tons, 389 ships of 1,281,649 tons and 345 ships of 1,184,364 tons respectively. Of the total being built 2,473,813 tons, or 47·6 per cent, were for registration outside the country of building. A total of 155 oil tankers of 1,990,719 tons was being built, representing 38·3 per cent of the ships under construction, and an increase of 267,239 tons since the end of March. In the world 1534 steamships and motorships of 7,223,004 tons gross were under construction, of which 28·1 per cent was the share of Great Britain and Northern Ireland. Oil tankers amounted to 217 ships of 2,824,020 tons, or 39·1 per cent of the tonnage being built. Tonnage under construction for export amounted to 2,938,718 tons, of which 15·8 per cent, was being built in Great Britain and Northern Ireland. The ships building included 161 between 6000 and 8000 tons, 133 between 8000 and 10,000 tons, 113 between 10,000 and 15,000 tons, 26 between 15,000 and 20,000 tons, 61 between 20,000 and 25,000 tons, 14 steamships between 25,000 and 30,000 tons, 5 steamships between 30,000 and 35,000 tons, and 1 steamship of 50,000 tons. Of the world total, 4,448,648 tons, or 61·6 per cent, were building under the inspection of Lloyd's Register.

Shipbuilding Orders for Abroad

AT a luncheon which followed the launch of the 47,150 deadweight tons tanker "Evgenia Niarchos" at the Barrow-in-Furness yard of Vickers-Armstrongs (Shipbuilders), Ltd., on August 8th, Mr. J. E. Dodds, speaking for the owners, said that it was the last of ten vessels built by the company for the Niarchos interests. He commented on the fact that although his firm had negotiated with Vickers-Armstrongs for dry-cargo ships, bulk carriers and tankers from 45,000 to 100,000 tons deadweight, it had been unable to approach the prices and deliveries obtainable elsewhere. For this reason orders for vessels totalling nearly 1,000,000 deadweight tons had been placed with other countries during the past fifteen months or so. Mr. Dodds deplored the fact that Vickers-Armstrongs had been unable to compete successfully for at least some of the new tonnage, and drew attention to the way in which this country—once the biggest shipbuilding country in the world—had been passed in tonnage laid down by Germany and Japan. In searching for the reason of this loss of work, Mr. Dodds said he had been shocked to hear an official statement that no less than 3,800,000 man-days had been lost in British industries during the past year as a result of industrial disputes. He did not know how much of this time had been lost by the shipbuilding industry, but urged both managements and men in the British shipbuilding industry to face up to the issues squarely and realistically, in an effort to regain and retain the pre-eminence which this country had enjoyed in shipbuilding for centuries.

Great North Road Improvements

THE Ministry of Transport and Civil Aviation has stated that two improvement schemes are to start this month on the Great North Road (A.1), as part of the general plan to double on this road between London and Newcastle. One scheme is for the construction of more than 5 miles of a second carriageway between Alconbury Hill and Woolpack Cross Roads, Huntingdonshire, at an estimated cost of more than £300,000. This scheme will include experimental sections. The other scheme provides for the improvement of the Sinderby Bridge, Yorkshire, and its approaches, at an estimated cost of £190,000. This will complete the duplication of more than 6 miles of the A.1 road between the junctions with the Ripon Thirsk Road (A.61) and the Burneston-Bedale Road (B.6285). The Ministry says that on

parts of the Alconbury Hill–Woolpack Cross Roads section the subsoil is of a uniform nature and in co-operation with the Road Research Laboratory experimental work is to be carried out in the course of research into the most economical kinds of road on various types of soil. The scheme when it is completed will provide twin carriageways, each 24ft wide, and approximately one-half of the second carriageway will be used for the experiment. More than a mile of the experimental length will be constructed in concrete and on the remainder various forms of flexible construction will be used with different kinds of surfacings. When the work is completed the Road Research Laboratory will keep all these sections under observation with the object of obtaining scientific data on the performance of and constructional thicknesses required for different kinds of road on this particular subsoil; naturally, this will have an important bearing on maintenance costs. The works on this section of the Great North Road were started before the second world war when land was purchased, earthworks carried out, and bridges constructed. The present scheme is a modernisation of the original one. The scheme has been designed and will be supervised for the Minister of Transport and Civil Aviation by the agent authority, the Huntingdonshire County Council, the county surveyor being Mr. T. H. Longstaff, M.I.C.E.

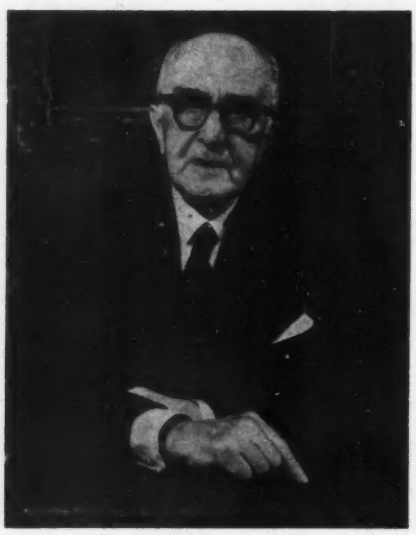
Obituary

SIR WILLIAM PATERSON

FOR more than fifty years, Sir William Paterson directed the affairs of the Paterson Engineering Company, Ltd., which he founded in 1902. His death, which we record with regret, occurred on Thursday, August 9th, a few days after his eighty-second birthday.

William Paterson, who was the son of James Paterson, was born at Roslin and began his technical education at the Heriot Watt College, Edinburgh. Thereafter he served an apprenticeship with a firm specialising in paper mill machinery. As a young man he was quick to see the increasing importance of water purification, and, as already noted, he decided at the beginning of this century to form a company for the development of that particular branch of engineering. As his business progressed, William Paterson introduced many new principles in the science of water purification. They included the excess lime process for softening and sterilising and the use of ozone as a sterilising agent. Another development was the use of chlorine gas for inhibiting algal growths in power station condensers, a method of treatment which, it has been suggested, has resulted, in this country alone, in a saving of probably 500,000 tons of coal a year. In the course of his career William Paterson filed over seventy British patents, many of them foreshadowing improvements which were not developed on a practical scale until years later.

But although the engineering aspect of water purification occupied the greater part of Sir William's distinguished career, there were other directions in which his technical skill was used to good effect. Among them was his outstanding service to the nation in the second world war. In 1938 Sir William was asked by Lord Waverley, who was then Sir John Anderson, Minister of Home Security, if he could devise an air raid shelter to give protection against blast and flying debris. Another requirement was that such a shelter could be rapidly produced in very large quantities at a minimum cost. The result of this request was the Anderson shelter; it was patented in order to prevent commercial exploitation, and Sir William Paterson presented the patent to the nation. His knighthood, conferred in 1944, was a recognition of this service. Throughout this period, and for several years after the war, Sir William continued to take an active part



Sir William Paterson

in the affairs of his company; he had, in fact, passed his eightieth birthday when, in January, 1955, he decided to retire from the chairmanship.

No account of Sir William Paterson's work could be complete without some reference to his services to a number of professional institutions. He was an honorary member of the Institution of Water Engineers and of the Royal Society of Health, an honorary fellow of the Heriot Watt College, a vice-president of the Junior Institution of Engineers, and a life member of the American Waterworks Association. Since 1910, Sir William had been a member of the Institution of Mechanical Engineers. He also served on the Committee of the Benevolent Fund of that Institution, revealing in his work for it that behind an apparently stern countenance there lay a heart easily softened to sympathy for those dogged by undeserved ill-fortune, and forgiving ever to those who in part bring sorrows and disasters on themselves.

VICTOR EDWARD PULLIN

WE regret to have to record the death last week of Dr Victor Edward Pullin, a pioneer of the use of radiological methods for the examination of engineering materials.

Dr. Pullin was born in Lancashire and was the son of a medical practitioner. He was educated at Exeter College, Oxford. No doubt it was as a consequence of the influence of his father that he seems at first to have contemplated becoming a medico, for he was a student of medicine and was qualified in that subject. But he never seems to have practised it. We have not been able to determine in the time available to us the exact course of events immediately thereafter. Some light is thrown upon it by the later history of his life. During the first world war he joined the Royal Engineers. In 1916 he was invalided out and went to Woolwich Arsenal Research Department as an assistant metallurgist. There the application of X-rays to the examination of the bases of high-explosive shells was under discussion. Dr. Pullin was asked to investigate the possibilities, partly, at least, because he had some medical knowledge of radiology. The suggestion is certainly conveyed that as a medical student his interests had already strayed in that direction.

Dr. Pullin threw himself heart and soul into this investigation and he soon foresaw what very considerable developments were foreshadowed by his work. Like all pioneers he was working under difficulties. He had to establish a small radiological section which involved, of course, finding others besides himself who would enthusiastically take up the work. In addition he had to design and have made by the section X-ray equipment capable of demonstrating successfully how useful radiological examination could be. Soon it was shown that X-ray examination could be usefully employed in the inspection of fuses and other assembled parts of weapons. Use was also made of the method for the examination of captured enemy ammunition.

So successful was he in demonstrating what could be done that in June, 1919, he was appointed Director of Radiological Research at Woolwich. Thereafter his whole life was spent in enlarging the field of application of radiological methods of examining materials. Possibly as a consequence of his medical training, he early appreciated the dangers to which operators of X-ray and other radiological equipment were exposed and he constantly drew attention in his publications to the precautions that needed to be observed. In due course he appreciated the possibility of using radioactive materials for examining materials. In delivering the Cantor Lectures to the Royal Society of Arts in 1925, for example, he showed for the first time some lantern slides of gamma radiography taken with radium. Thereafter, he delivered many lectures and read many papers before learned societies revealing the progress made in the field that he had especially made his own. Many articles from his pen appeared in this journal, and in 1934 he published a book entitled *Engineering Radiography*.

His own work was principally done to meet the needs of the Services. The Army was mainly concerned with the examination of ammunition and fuses, the Navy with that of steel castings and welds—it is interesting to reflect that but for his work the progress in the use of welding would probably have been much delayed—and the Air Force with that of light alloy castings. But industry in general found applications for his work and its great value was recognised in 1933 when he was made C.B.E. In September, 1938, he retired from his job as Director of Radiological Research to set up an independent consulting practice. During the second world war he was called upon by the Ministry of Aircraft Production as a consultant and he was consultant to the Ministry of Supply at the time of his death.

The loss of Dr. Pullin to workers in radiological fields is a severe one. But it is an even more severe one to his friends, amongst whom we reckon ourselves. For Dr. Pullin was a charming character, easy to work with and very appreciative of the work of others; entertaining, too, to talk to, and within his own subject, one about which no one knew more than he, he combined enthusiasm with the modesty that only the great possess, the modesty to realise how very much more there still is to know.

Further French Locomotive Experiences

By EDWARD H. LIVESAY

(*Continued from page* 190, *August* 10*th*)

No. II—PARIS/HAVRE EXPRESSES

PLANNING the routes and locomotives likely to prove especially interesting, it seemed that the services to Havre and Cherbourg should be on the list, as not only were the trains running to these Channel ports fast and heavy, but the engines running them were essentially of the very kind I have referred to as typical of Monsieur Chapelon's work; that is, not of the latest design, but machines rejuvenated by the embodiment of devices and principles advocated by him for so long. At our first meeting, when outlining my plans, he endorsed this suggestion, promising that arrangements would be made to further it, and the following two articles will deal with runs made with these rebuilt engines working trains between Paris, Havre and Cherbourg.

Their prototypes were "Pacifics" built for the Paris/Orleans Railway in 1912, and rebuilt in 1929 with high superheat, 752 deg. Fah., a steam circuit right through from regulator to exhaust double the original capacity, Lentz oscillating cam poppet valve gear, and Kylchap double blast pipes. The benefit of these alterations was so evident that Monsieur Dautry, at that time general manager of the Etat Railway—of which the Paris/Havre/Cherbourg lines form part—directed the motive power department to study these engines, and embody their chief features in 283 "Pacific" locomotives which it was planned to rebuild with Chapelon improvements. These engines, like the Paris/Orleans machines, had been built some years before—the first began running in 1914—and were basically very similar to the latter, save for minor details, such as Crampton fireboxes in place of Belpaire, leading bogies with rod centering in place of the Alsatian Railway's spring control, and trailing trucks with pivoted yoke anchorage instead of lateral guides, shown in Fig. 1. After consideration it was decided to modify these 283 engines further by fitting thirty-unit Schmidt superheaters in place of twenty-four; enlarging the steam passages as far as the high-pressure cylinders, while leaving the high-pressure piston valves unchanged, and giving the low-pressure cylinders poppet valves of the Dabeg type. One hundred and thirty-four of these Etat "Pacifics" were thus reconstructed and are still running; Fig. 2 illustrates one of them.

While giving excellent results, this partial rebuilding did not enable the engines to give quite the same output as the Paris-Orleans machines, so further modifications were made to twenty-three engines subsequently taken in hand, which were given Willoteaux slide valves of the double-port admission and exhaust pattern; six others were fitted with Renaud poppet valve gear to the low-pressure cylinders, which was afterwards removed and Lentz gear substituted. Finally, thirty-one engines underwent a complete transformation, being given Dabeg poppet valve gear to both sets of cylinders and Kylchap double exhaust pipes and chimneys (Figs. 3 and 4). Though these thirty-one engines during tests reached about the same output as their Paris/Orleans models, in service they give rise to certain difficulties and to somewhat higher consumption, resulting from valve leakage, the form of seatings being new. Eighty-two other engines were given a simple Kylchap exhaust, high-pressure cylinders with piston valves of large area, steam chests and supply pipes of ample volume, the original low-pressure cylinders being retained. Altogether 270 of the 283 engines were rebuilt as above, the remainder being given merely a Kylchap exhaust.

The output of some of these different types of engines at 68·6 m.p.h. (110km) is approximately as follows:—

(1) The engines fitted with Willoteaux slide valves to the low-pressure cylinders, simple Kylchap exhaust and high superheat, similar to the "D" series on which I rode, develop 2000 h.p.

(2) Engines with double Kylchap exhaust, high superheat, large steam pipes and Lentz valve gear to all cylinders, develop 2500 h.p. The Nord engines employed on the "Golden Arrow," fully described in the first series of these articles, are of this type; some were transferred from the Paris/Orleans to the Nord.

(3) The original Paris/Orleans engines, and of the Est type "C"—similar to the one on which I rode from Strasbourg to

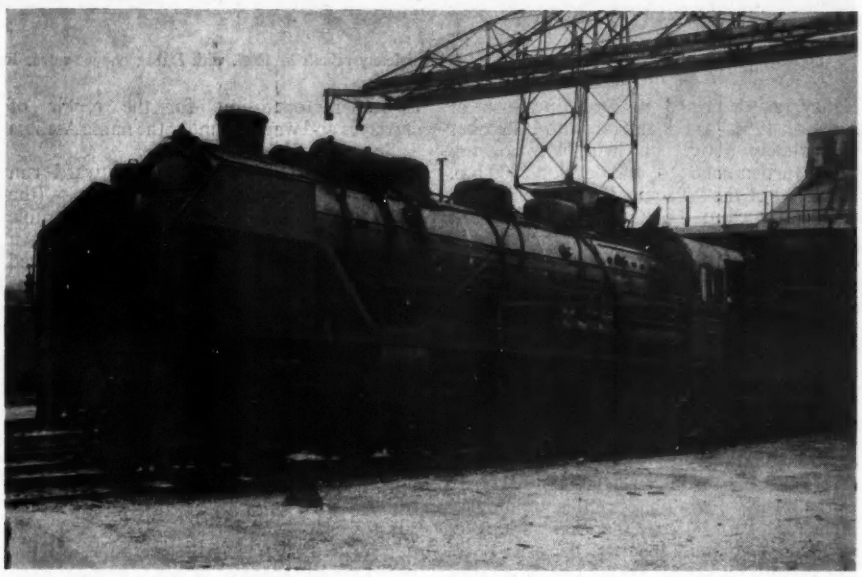


Fig. 2—"Pacific" locomotive, Etat Railway, as rebuilt in 1932 with thirty-unit Schmidt superheaters and Dabeg low pressure poppet valves

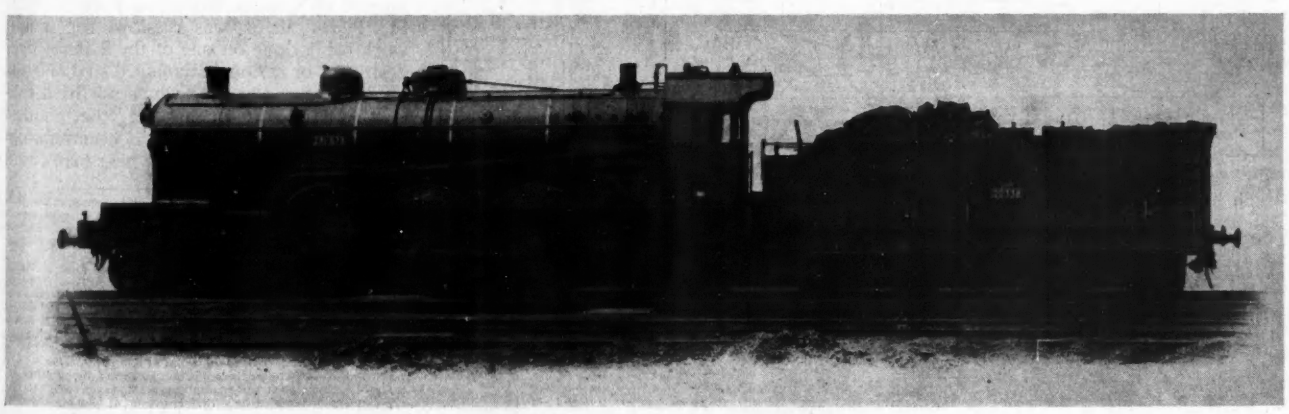


Fig. 1—Etat "Pacific" as built in 1914. These locomotives were rebuilt as shown in Fig. 2 above

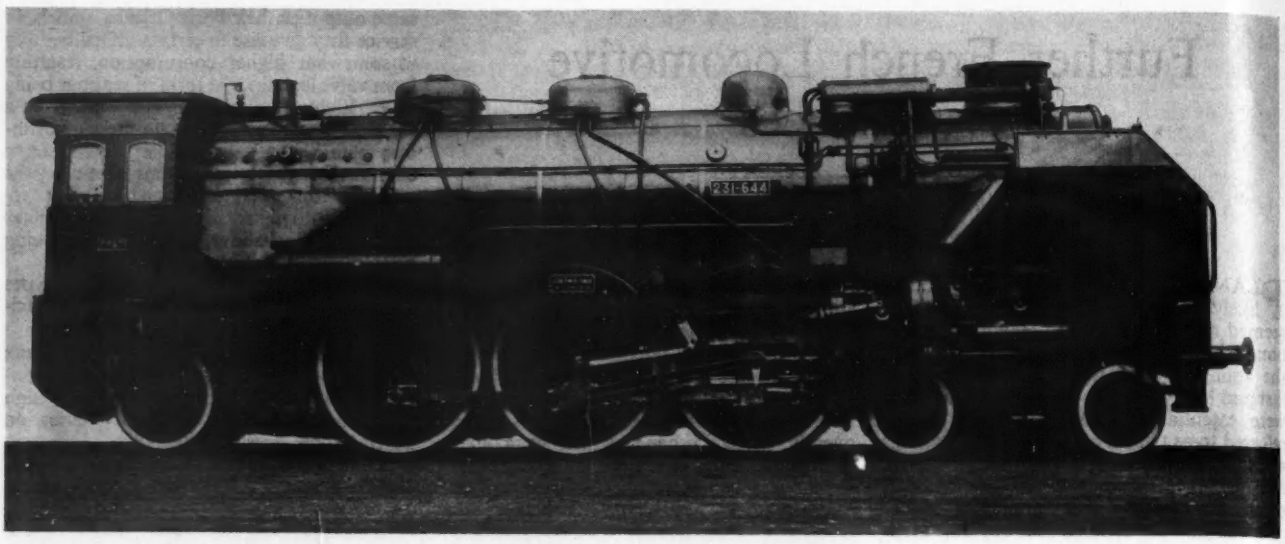


Fig. 3—"Pacific" locomotive, Etat railway, as completely rebuilt in 1935, with Dabeg poppet valves for all cylinders and Kylchap double exhaust pipes

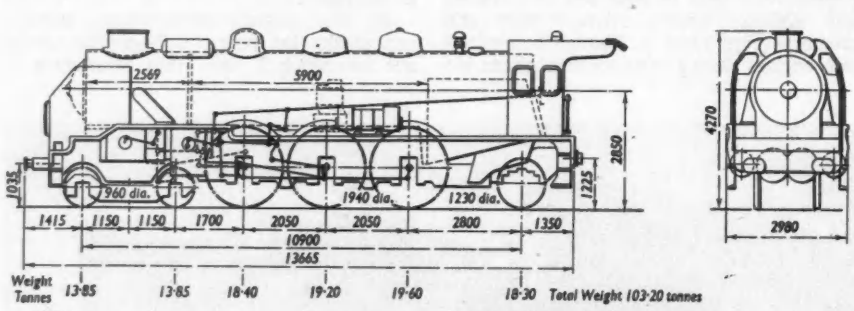
Nancy, as described in THE ENGINEER of June 4, 1954—are identical with the ones immediately above, but with low-pressure valves further enlarged, and develop 2800 h.p.

Several of the "Pacifics" on which I rode were stationed at the Batignolles depot, just outside the Gare St. Lazare; thirty-six of the type are of the "D" series, and nine of the "G," which are "DD" class completely rebuilt; the return run from Havre was made with No. 231—G703.

The profile of the line from Paris to Havre (Fig. 5) shows that there is nothing particularly difficult about it as far as Sotteville, a southern suburb of Rouen, where a long climb begins, ending at Yvetot, followed by easy fluctuations to Virville, and then a severe descent through Harfleur into Havre. In the reverse direction, once this preliminary incline is surmounted, there is nothing of real importance all the way back to Paris. But it is an interesting route, one of the first railways built in France, two famous British engineers, Mackenzie and Brassey, being responsible for its survey and construction, as from Paris to Rouen in 1843, and thence to Havre in 1847. Another well-remembered English pioneer railwayman, J. Buddicom, undertook to supply the locomotives working the line, and undertakes their repair and maintenance, which was carried out in works built by him at Sotteville. This establishment is still in operation, for the repair of carriages and wagons, under the name Ateliers de Sotteville-Buddicom.

The engine on which the outward run from Paris was made, No. 231–D— (the latter part of the number is indecipherable in my notebook) was of the same type, a rebuilt Chapelon "Pacific," as employed on the Cherbourg trains dealt with in the next article. Monsieur Devaud, superintendent at Cherbourg, accompanied me, and Chief Mecanicien Moignier was also in the cab; the enginemen were Messieurs Frechon and Gognet. Though there is actually room for five individuals in these somewhat abbreviated cabs, it cannot be said that swinging a cat in them is a practical proposition under these circumstances. The train, loaded to nearly 600 tons gross, left the Gare St. Lazare punctually at 8.45 a.m. in pouring rain; nevertheless, adhesion was not lost—it seldom is with French locomotives, in my experience. I was advised that the steam chest gauges were not quite accurate, so they will not be quoted, but the boiler pressure was well up to the working 16 atm., the regulator at the start was full, and the respective high and low pressure cut-offs were 48 and 60 per cent—yet there was no slipping, with 600 tons—do not ask me why. Flaman recorders are found in different positions on French engines, but always where they can be read with little or no difficulty; they are never stowed away under the fireman's seat, for instance, as they were on "A4s" before the war. (Now they are probably stowed away in store, not being found in the cabs at all.) On this engine the recorder was below the front window, right in front of the driver, an ideal position. The working timetable, in its neat frame, was also practically under his eye, to be consulted at a glance; that is an arrangement we should certainly adopt in Britain. Both Flaman and timetable are as easily read at night as by day, thanks to electric light. Every French locomotive, from express to yard shunter, steam, electric and diesel, is equipped with all these amenities. When shall we reach that happy and efficient stage?

The first part of the journey, from Paris to Mantes, will not be described in detail, as it forms part of the Cherbourg route in the next article, and it also comes into the latter part of the present one. The profile shows there are no gradients worth concern until Mantes is reached; a fine new roundhouse was noticed as we ran through that town, a post-war replacement, very modern in layout, similar to several seen at different places in Northern France. At Mantes the line forked, the left-hand tracks swinging off in the direction of Cherbourg, and those to the right, which we were following, to Havre, thus missing the great 1 in 110 climb through Mantes-Gassicourt to the Breval peak on the former route. Our train carried on over a much easier stretch, through Vernon and Gaillon* to Sotteville, at the beginning of a long climb through Rouen to Yvetot. Near St. Pierre there was a slow for repair work being done on one of the 2700 bridges destroyed or seriously damaged in 1944, the invasion year, when the whole northern railway system was disrupted; the greatest credit is due for the way it has been rehabilitated. Water was picked up near here; not



Cylinders :		Kylchap double chimney and blast pipe	
h.p. (two)	16·5in by 26·0in	"Dabeg" oscillating cam poppet-valves	
l.p. (two)	25·2in by 26·0in	A.C.F.I. feed-water heater	
Ratio h.p. to l.p.	2·32	Electric light by turbo-generator	
Wheels, driving, diameter	6ft 5in	Flaman recorder	
Pressure	238 lb/sq. in	Valves (poppet) :	
Heating surface :		Diam. adm. h.p.	185mm
Firebox	178 sq. ft	Diam. exhaust h.p.	195mm
Large tubes	750 sq. ft	Diam. exhaust l.p.	240mm
Small tubes	1167 sq. ft	Lift h.p.	24mm
Superheater	657 sq. ft	Lift l.p.	28·5mm
Total	2752 sq. ft	Travel min. h.p.	8mm
		Travel min. l.p.	20mm
Grate area	46·6 sq. ft	Travel max. h.p.	76mm
Weights as per diagram		Travel max. l.p.	85mm
Speed limit	80 m.p.h.	Tractive effort	33,000 lb

Fig. 4—Rebuilt "Pacific," Western region, S.N.C.F. Type 231 "G" and "D"

* A place with very early automobile associations. In 1900 and onward, competitions up Gaillon Hill were an annual event, and on one occasion, I believe 1902, the climb was won by a 50 h.p. Napier, the first racing car to be built by that company. It was a gargantuan machine, weighing over 3 tons, built in 1901, for the Gordon-Bennett race of that year, but had to be scratched at the last moment when it was found that the British tyres were quite unable to stand the combined stress of great weight and high speed (85 m.p.h.). Fitted with French tyres it ran in the Paris–Bordeaux race, but retired with clutch trouble. It ran in the 1901 Paris–Berlin race also, but broke a spring and again retired. The four-cylinder engine had a bore and stroke of 6½in by 7½in, and developed 70 b.h.p. at 850 revolutions. There was no throttle, engine speed being governed by altering the point of ignition, so fuel consumption remained the same whether the car was driven fast or slow. However, it was not intended to go slow. I saw it several times in full flight, an awe-inspiring sight, and my boyish enthusiasm for it was extreme, but diminished subsequently when its limitations and crudities became obvious—E.H.L.

only the tank, but my boots were quickly filled, the two-men-one-lever control of the scoop being rather awkward to manage when being withdrawn. This was one of the very few fittings seen on French locomotives I did not altogether approve of; evidently the tenders and the scoop equipment were both old fashioned. But even the more up-to-date British arrangement can be obstreperous at times; it happened that only a week or two before I had been nearly washed out of the cab by a cascade of coal and water on a 4–6–0 *en route* from Leicester to St. Pancras; according to the fireman the scoop jammed, and it wasn't his fault. These are by no means the only instances I have noticed of a flooded tank.

The Oisel stop was made at 10.03; 80 miles had been covered in 78 min, 61·5 m.p.h.; departure took place at 10.10. There had been nothing very strenuous about the route so far, but at Sotteville things became more demanding; junctions, gradients, many bridges (some over the Seine), sweeping curves bringing Rouen Cathedral into the picture, to be seen from many viewpoints, and through three tunnels into one of Rouen's four stations, this one being designated R.D., where the train came to a stand at 10.14. Away again, plunging straight into the St. Maur tunnel, two-thirds of a mile long, simultaneously climbing mostly at 1 in 200, the ascent punctuated by four tunnels to the peak at Motteville and a stop there at 10.51, 1 min late. The 19-mile bank had been climbed in 33 min, the gradient beginning right at the Rouen platform, with wet rails in a greasy tunnel, and a 600-ton load. Considering the age of the engine, which had barely 55 tons available for adhesion, the performance was decidedly good.

Yvetot, and another stop; then along a wide, windy ridge with easy gradients, until suddenly the line dropped over the northern edge, beginning a descent of 11 miles without a break into Harfleur, mostly at 1 in 125; 3½ miles farther the train came to a stand in the new Havre terminus, which replaces one destroyed in the war, at 11.45, 2 min early.

The return run to Paris will be dealt with briefly; for all it was such a good one, the engine being of much the same type as that employed in the morning on the outward trip, and the load very light, a little over 300 tons. With Messieurs Devaud and Moignier, and enginemen Rahnou and Linon in the cab, No. 231-G703, a Chapelon "Pacific" rebuilt in 1947 with Walschaerts-operated Dabeg oscillating cam poppet valves for both sets of cylinders, pulled out of Havre at 5.42 p.m. in weather dull but fine, a considerable improvement on the morning's variety, but breezy, making it somewhat chilly on that rather open footplate. I noticed this engine was exceptionally clean; the cab fittings almost glittered, which I put down at first to its being a Havre machine starting from scratch, with a Havre official, Monsieur Moignier, riding on it. Or could the presence of a foreign observer have had anything to do with it? Perhaps! It was nice being able to read the spotless gauges without difficulty, even from a distance, and therefore a pity that on this particular run I did not see the necessity to consult them very often. Later I learned it was a Batignolles engine.

Acceleration away from the platform and up the immediate heavy gradient out of Havre was rapid, and the severe 6-mile climb from Harfleur to Virville, 1 in 125, was taken correspondingly fast, only to be expected in view of the light load, a mere bagatelle to No. 231-G703. The riding of this veteran at speed was particularly good; in fact, perfect; there was no opposing motion whatever between engine and tender, or in any direction; there is evidence of this on some modern classes of British engines I could mention. A stop was made at Rouen, and water taken; thence it was non-stop to Paris, with the speed uniformly high, long stretches being covered at near the route limitation of 120km; nothing seeming to be much below it. But the speed, load and gradients all together called for no particular effort from the engine, this being borne out by the steam-chest gauges, their needles generally flickering gently in the neighbourhood of 10 atm. h.p. and 1½ l.p., showing that the latter had little to do except on the brief upward pitches. We came to a stand in the Gare St. Lazare at 8.01 p.m., 1 min early, having made 141 miles with one 6 min stop in 139 min, an inclusive average of 61 m.p.h. One of the fastest runs I made in France, but with one of the lightest loads—and one of the oldest engines.

When leaving France, the Havre/Southampton route was chosen in preference to that via Calais, which I had already travelled over three times with the "Golden Arrow"; the run to Havre is worth dealing with in outline, as the train proved fast and heavier than either of the others covered by this article; very heavy in fact—800 tons. The run climaxed the tour, and gave a perfect demonstration of what these old Chapelon "Pacifics" can still do in their later years.

Neither interpreter nor official was accompanying me this time; possibly it was considered that now I should be quite at home in French cabs and, moreover, had been over this route twice before on the same type of engine. However, two representatives of the S.N.C.F., at opposite ends of the scale showed the good-fellowship I had found typical of all ranks and ratings by coming to see me off—Monsieur Segaud, chief of the test division, and Chauffeur Cresson, who was prominent in Article V of the first series, dealing with the 2–8–2 tank engines on the Paris local "pull-and-push" trains. The train left the Gare St. Lazare punctually at 5.15 p.m., headed by "Pacific" No. 231-D681, a rebuilt Chapelon from the Batignolles depot, in charge of Mecanicien Descroix and Chauffeur Lelandais, a friendly pair with whom I soon settled down despite the absence of an interpreter to act as go-between. The load was 770 tons net, say, 800 tons gross, one of the heaviest I came across in France; the weather was fine but cool and dull. This was not the boat train, which followed a couple of hours later; it had been chosen because it did most of the distance in daylight—despite electrically-lit cabs, I am not enamoured of footplate travel after dark. Over the broad Seine at Asnieres, I saw first the station flash by and then le Rue Henri Barbusse, from which I had so often watched the varied traffic, for the last time. The engine was making light work of the trailing 800 tons; going through Poissy, at the foot of the long, easy drop from Acheres, it was checked to keep within the engine's limitation of 72 m.p.h.; the track limit here was, I believe, 75 m.p.h. A long level stretch beside the Seine followed, I think the longest between Paris and Havre; then there was nothing of importance in the shape of gradients with the exception of a couple of miles of 1 in 200 up through Maisons-Lafitte until a similar rise into Mantes; after that nothing more until Sotteville, nearing Rouen. The Mantes incline was taken at an easy 60 m.p.h.; through Vernon, at the top of a similar rise, which was rushed, the engine blew-off—with 800 tons—and this was a hand-fired engine! Here I jotted down: "48 miles in 45 min, 64 m.p.h.; a noble veteran this." A good fireman, too, and I mustered enough French to tell him so. Round the many sweeping curves, over bridges and through tunnels into Rouen, by this time so familiar, where the train came to a stand at 6.42; 86 miles in 87 min, 59·3 m.p.h. Leaving again at 6.45—no water was taken here—the long climb through four tunnels to Motteville was taken unconcernedly; at Yvetot, where we stopped, Descroix went round the engine, presumably a precautionary measure against the long and steep drop right into Havre, down which brake gear would get a testing. He was using a fine acetylene lamp which had been lighted in readiness at Rouen—I don't remember seeing slush-lamps used on the S.N.C.F. This steep 1 in 125 descent into Harfleur and Havre was taken at high speed; I should think full speed, 72 m.p.h., but this was guess work, I being in the fireman's seat, out of sight of the Flaman, and darkness had fallen. The Rouen/Motteville climb, 19 miles of heavy slogging had been made in 30 min, or at 38 m.p.h., very good going with such a heavy train. It came to rest in the new terminus at Havre at 8.05 p.m., no doubt O.T. or early, but I seem to have omitted asking about this—or to read the working timetable, which, as usual, hung right in front of the driver. The 131 miles from Paris had been done in 145 min, inclusive of three stops, an average of 54·2 m.p.h. Allowing for these, the average had been 58·5 m.p.h.

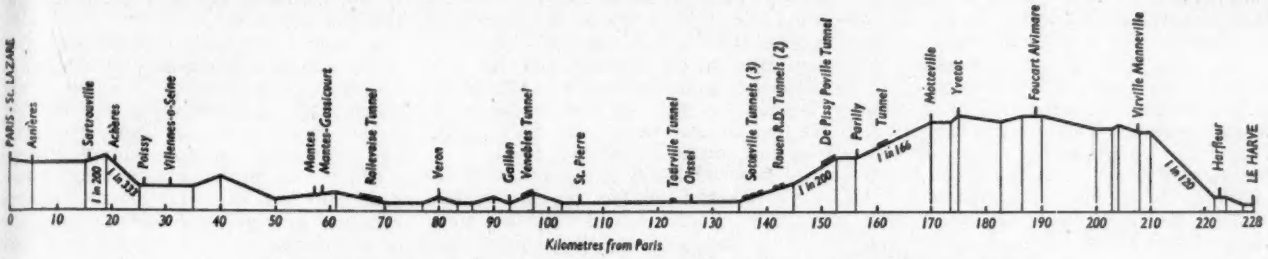


Fig. 5—Condensed profile of the route from Paris to Havre. The ruling gradients are indicated

(To be continued)

Resonance Stress Testing

By B. BRAMALL, B.Sc., A.M.I.C.E.

In this article a theory is presented and techniques discussed for determining experimentally the longitudinal load in a structural member. The method involves establishing transverse vibrations by means of external excitation and measuring the response at the three-quarter length positions. The applications discussed are to members with high self loads, due to constraints or the weight of the structure, such as occur in civil engineering frameworks or prestressed concrete.

IT is the purpose of this article to put forward, rather tentatively, proposals for a method of structural testing which has as its object the measurement of those forces and stresses which are contained by a structure in its natural condition before the application of any live or special test load. The author discerns, in the increased use of statically indeterminate frames and the preponderance of "dead load" in the larger creations of the structural engineer, an implied but insistent need for means of verifying these forces by instruments.

Scale model tests cannot in all circumstances meet the underlying requirements. They tell us nothing of the yielding of constraints such as are occasioned by movement of foundations or creep in the members.

Conventional methods of testing with various forms of extensometers and deflectometers are invaluable as a means of measuring the strains due to the application of a known load, but they offer little possibility of detecting those forces which are due to the self weight of the structure, or to the constraints which might be suspected of changing during its life.

Often, in fact, we are apt to consider many structures to be determinate when they are not strictly so. It is obvious that, for instance, the stiffened suspension bridge, or any continuous span is statically indeterminate ; it is not so obvious at first sight that extra restraints are introduced in "simply supported" bridges by using more than two main girders, in roof trusses by the continuity of purlins, or in towers by supporting them on four points.

In many cases if the force in one member forming part of a structure could be checked, it would provide the key for solving the forces throughout, depending, of course, on the total number of redundancies. In some cases knowledge of the force in more than one member would be required. By way of example, a "locked cantilever" bridge continuous over four supports would require a knowledge of forces in two members of each truss to provide a general solution of forces in each truss. Given the facility of measuring these locked-up forces, the engineer would no doubt take the opportunity of measuring a greater number than the theoretical minimum.

In the quest for a means of discerning the absolute force in a member, a possibility is suggested by the interrelation between its natural frequency of vibration and the longitudinal force. The interrelation is exploited in tuning a violin string. In a crude way it is often used as a check on the tensioning of bicycle wheel spokes : the note produced when the spoke is plucked gives some indication of its tension.

The principle finds quantitative application in engineering practice in the Maihak extensometer. The note emitted by a wire stretched between clamps on the test member is matched to the note of a similar wire which can be stretched to a measurable degree. Matching, which is performed before and after application of the load, can be effected very accurately by elimination of beats. Increase in strain due to the load is found by the known change in strain of the datum wire. In most cases the dead load strain is not measurable owing to the impossibility of relieving the structure of its own weight, and redundancies. Only if such wires are attached to parts of the structure during erection is it possible to establish its absolute strain. Possibility of differential creep between the member and the wire renders long-term observations impracticable.

In all these cases the slenderness of the vibrating member makes the effect of end fixity and angular momentum small. In a stiffer member, rigidity of the end fixing will have a powerful influence on the vibration frequency ; fixed ends will result in a much higher natural frequency than hinged ends. If angular momentum becomes significant it will tend to decrease the natural frequency, other factors remaining constant.

Correlation of stress with natural frequency applied directly to vibrations of a structural member would, therefore, appear to be limited to long flexible ties. If vibrations are sustained by mechanical or electrical vibration generators which are capable of variation over a range of frequencies, a natural frequency can be found at its greatest response in amplitude. From the frequency, stress might then be established.

Comparatively few components approximate to the ideal long flexible wire, and a more generally useful application will have to take account of the influence of end fixity. Theoretical determination of this is difficult and liable to serious error.

The degree of end fixity, however, has a direct influence on the mode of vibration. For perfectly rigid fixing, the slope of the member will remain constant at the ends throughout the cycle, whereas for less than perfect rigidity there will be a change of slope from the neutral. For small amplitude vibrations of a given member there will be one characteristic mode of vibration corresponding to one set of end conditions. Amplitude of vibration will influence maximum deflections at all points along the member in the same ratio. If, therefore, we obtain a measure of the maximum slope at both ends, expressed in proportion to the amplitude of the motion described by one point in the member, we have in effect a measure of the fixity of both ends. Three experimentally determined measurements in addition to that of primary frequency should therefore be adequate to give all the information required.

End slope in relation to the deflection of a given reference point in the member is a direct effect of end fixity, but there is no reason why the measurement of change in slope should not be replaced by a measurement of amplitude at a finite distance from the ends. If, for instance, we are able to measure the amplitude at the centre point and at both quarter points, we have three measurements, which in a somewhat modified way give us the same basic information, and by expressing the quarter point amplitudes as a ratio of the centre point amplitude, the effect of magnitude of the mode is cancelled. The two ratios are an indirect measure of stiffness in supports at both ends, and should therefore enable us to determine a relationship between frequency and stress, and thereby evaluate the latter from a knowledge of the former.

Such indirect assessment of end fixity, used as a step in finding a relationship connecting stress with natural frequency, may appear involved. We are not concerned with end fixity except to this extent, and there is no good reason why it must be found if it is possible to obtain the mathematical relationship of stress and frequency directly from the two ratios.

It will be shown later that measurement of change in curvature at three chosen points will serve the same purpose as measurement of amplitude, giving both theoretical and practical advantage.

It might be mentioned here that any instruments attached to the member undergoing test must be of low mass and low inertia. Electric vibration generators are available having armatures of exceedingly small mass, and resistance strain gauges commend themselves in this respect as measuring devices. Care must be taken to mitigate the inductive effects of stray magnetic fields set up by the vibration generator. Base support of such a generator should be rigid, and since it will generally be impracticable to support it independently of the structure careful consideration will be required. In a triangulated frame, suitable support may be provided at a vertex. In some locations it should be practicable to transmit the impulses from the armature through a light cable maintained in tension by a spring anchorage on the opposite side of the member.

The instantaneous change in curvature from that in the neutral position can be measured by the differential resistance of two strain gauges attached to opposite sides of the member.

This general reasoning is supported by the following consideration of the equation representing the balance of forces and mass accelerations :—

$$EI\frac{d^4y}{dx^4}-P\frac{d^2y}{dx^2}-mk^2\frac{d^4y}{dt^2\,.\,dx^2}+m\frac{d^2y}{dt^2}=0 \quad . \quad (1)$$

in which

x = distance from a fixed reference point along the axis of the member.
y = lateral displacement from neutral position of a point in the member at any instant normal to minor axis of section (vibrations assumed to be in the plane parallel to the major axis).
E = modulus of elasticity.
P = initial force in member applied longitudinally, and is positive for tensile force.
a = cross sectional area of member.
k = least radius of gyration of the section.
$I=ak^2$ = least moment of inertia of section.
m = mass per unit length of member.
t = time, taking as origin an instant when the member is passing through its neutral position ($y=0$).
L will be used to denote the total length of the member.

If it is assumed that motion of any point is simple harmonic and defined by $y=Y\sin\omega t$, where ω = angular frequency of S.H.M., a general solution for Y is

$$Y=A\sin bx+B\cos bx+C\sinh ax+D\cosh ax \quad . \quad . \quad . \quad . \quad . \quad (2)$$

in which A, B, C and D are all arbitrary constants and

$$a=\sqrt{\frac{\sqrt{4EIm\omega^2+P_1^2}+P_1}{2E^2I^2}} \qquad P_1=P-mk^2\omega^2.$$

$$b=\sqrt{\frac{\sqrt{4EIm\omega^2+P_1^2}-P_1}{2E^2I^2}}$$

The expressions will be made simpler by introducing two dimensionless groups

$$\alpha=\frac{P_1L^2}{EI}=\left\{\frac{P-mk^2\omega^2}{EI}\right\}L^2$$

$$\gamma=L^2\omega\sqrt{\frac{m}{EI}}.$$

Then

$$aL=\sqrt{\frac{\sqrt{4\gamma^2+\alpha^2}+\alpha}{2}}$$

and

$$bL=\sqrt{\frac{\sqrt{4\gamma^2+\alpha^2}-\alpha}{2}}.$$

It will be useful at the present stage to review the known and unknown quantities.

There are many values of ω which will satisfy, but for any particular case they are all discrete. If the fundamental frequency has been found experimentally then one of these discrete values ($\omega=2\pi\times$frequency) is given data.

γ therefore involves quantities which are all known, and α involves only one unknown quantity, P.

A, B, C, D and α are unknown quantities defining Y for given value of x. Of these six variables, α may be regarded as the required quantity, since it is related to P in a simple manner.

α is a complex function of A, B, C, D, and Y for any given value of x. By utilising values of Y corresponding to known distances x from the origin, we may eliminate the variables defining α. Should there be no *a priori* knowledge of any end conditions, clearly at least five relationships between Y and x must be furnished by measurements at five different places along the member. Any known end condition may serve the same purpose, such as :

(1) Fixed location in space, or
(2) freedom from spatial restraint,
(3) fixed in direction, or
(4) freedom from directional restraint.

Generally in the case of a member forming part of a framework, both ends may be assumed as fixed in position. It will not usually be possible to make any assumption regarding directional restraint. Thus, having knowledge of two end conditions, the minimum number of amplitude measurements required will be three. A suitable choice of locations for these measurements will be at the half and both quarter points.

Before leaving these preliminaries it might be observed that in the special case when four end conditions can be specified, there is no need for a fifth relationship between Y and x. The anomaly is explained by reference to equation (2), from which it will be seen that A, B, C, D, and Y may all be increased in a common ratio without making that relationship invalid. Fundamentally we are concerned with the ratios between these five, that is to say, four ratios are sufficient. End conditions specify ratios, but when we rely on measurements of amplitude one measurement is used in establishing finite values.

End Conditions

It will be assumed that there will be negligible lateral end displacements, so that $Y=0$ at both extremities.

Mathematics will be simplified considerably by taking as origin for x the centre point of the member. At one end x will be $L/2$ and at the other end x will become $-L/2$. Symmetry is by no means inferred, but the convenience will soon be appreciated.

Now putting $x=L/2$ and $x=-L/2$ in the general solution for Y (equation (2)) and equating to zero:

$$Y_{(x=L/2)}=+A\sin\frac{bL}{2}+B\cos\frac{bL}{2}+C\sinh\frac{aL}{2}+D\cosh\frac{aL}{2}=0$$

$$Y_{(x=-1/2)}=-A\sin\frac{bL}{2}+B\cos\frac{bL}{2}-C\sinh\frac{aL}{2}+D\cosh\frac{aL}{2}=0.$$

Therefore

$$D=-B\frac{\cos bL/2}{\cosh aL/2}.$$

$$C=-A\frac{\sin bL/2}{\sinh aL/2}.$$

The general solution may be rewritten:

$$Y=A\left\{\sin bx-\frac{\sin bL/2}{\sinh aL/2}\sinh ax\right\}+B\left\{\cos bx-\frac{\cos bL/2}{\cosh aL/2}\cosh ax\right\}.$$

Also

$$Y'=A\left\{b\cos bx-a\frac{\sin bL/2}{\sinh aL/2}\cosh ax\right\}+B\left\{-b\sin bx-a\frac{\cos bL/2}{\cosh aL/2}\sinh ax\right\}$$

$$Y''=A\left\{-b^2\sin bx-a^2\frac{\sin bL/2}{\sinh aL/2}\sinh ax\right\}+B\left\{-b^2\cos bx-a^2\frac{\cos bL/2}{\cosh aL/2}\cosh ax\right\}.$$

where

$$Y'=\frac{dY}{dx} \quad \text{and} \quad Y''=\frac{d^2Y}{dx^2}.$$

Since by definition, $y=Y\sin\omega t$, we may introduce amplitude ratios which are independent of time :

$$Q_1=\frac{y_{(x=L/4)}}{y_{(x=0)}}=\frac{Y_{(x=L/4)}}{Y_{(x=0)}}$$

and

$$Q_2=\frac{y_{(x=-L/4)}}{y_{(x=0)}}=\frac{Y_{(x=-L/4)}}{Y_{(x=0)}}.$$

Then,

$$Q_1=\left[\frac{\frac{A}{B}\left\{\sin\frac{bL}{4}-\frac{\sin bL/2}{\sinh aL/2}\sinh\frac{aL}{4}\right\}+\left\{\cos\frac{bL}{4}-\frac{\cos bL/2}{\cosh aL/2}\cosh\frac{aL}{4}\right\}}{\left\{1-\frac{\cos bL/2}{\cosh aL/2}\right\}}\right]$$

and

$$Q_2=\left[\frac{\frac{A}{B}\left\{-\sin\frac{bL}{4}+\frac{\sin bL/2}{\sinh aL/2}\sinh\frac{aL}{4}\right\}+\left\{\cos\frac{bL}{4}-\frac{\cos bL/2}{\cosh aL/2}\cosh\frac{aL}{4}\right\}}{\left\{1-\frac{\cos bL/2}{\cosh aL/2}\right\}}\right]$$

Q_1 and Q_2 will be termed quarter point coefficients of amplitude.

In a precisely similar way may be introduced quarter point coefficients of curvature, which again will be true at any instant :

$$K_1=\frac{Y''_{(x=L/4)}}{Y''_{(x=0)}} \quad \text{and} \quad K_2=\frac{Y''_{(x=-L/4)}}{Y''_{(x=0)}}.$$

Then

$$K_1=\left[\frac{\frac{A}{B}\left\{b^2\sin\frac{bL}{4}+a^2\frac{\sin bL/2}{\sinh aL/2}\sinh\frac{aL}{4}\right\}+\left\{b^2\cos\frac{bL}{4}+a^2\frac{\cos bL/2}{\cosh aL/2}\cosh\frac{aL}{4}\right\}}{\left\{b^2+a^2\frac{\cos bL/2}{\cosh aL/2}\right\}}\right]$$

and

$$K_2=\left[\frac{\frac{A}{B}\left\{-b^2\sin\frac{bL}{4}-a^2\frac{\sin bL/2}{\sinh aL/2}\sinh\frac{aL}{4}\right\}+\left\{b^2\cos\frac{bL}{4}+a^2\frac{\cos bL/2}{\cosh aL/2}\cosh\frac{aL}{4}\right\}}{\left\{b^2+a^2\frac{\cos bL/2}{\cosh aL/2}\right\}}\right]$$

From the above it follows that

$$Q_1+Q_2=\frac{2\left\{\cos\frac{bL}{4}-\frac{\cos bL/2}{\cosh aL/2}\cosh\frac{aL}{4}\right\}}{\left\{1-\frac{\cos bL/2}{\cosh a/L2}\right\}}$$

and

$$K_1+K_2=\frac{2\left\{b^2\cos\frac{bL}{4}+a^2\frac{\cos bL/2}{\cosh aL/2}\cosh\frac{aL}{4}\right\}}{\left\{b^2+a^2\frac{\cos bL/2}{\cosh aL/2}\right\}}$$

It will be noted that these latter expressions are independent of A and B.

Graphical Representation

For any given values of ω and P or P_1, or their corresponding dimensionless equivalents

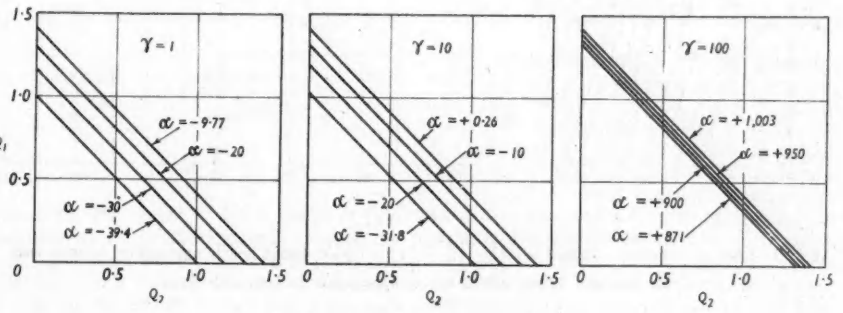


Fig. 1—Q_1 and Q_2 for various values of α and γ

γ and α, quantitative values can be given to a and b.

Figs. 1 and 2 show the relation between Q_1, Q_2, and K_1, K_2, respectively for particular values of γ and α. If a measured frequency happened to give a value for γ, corresponding to one of the graphs, it would be possible by determining the ordinates according to the quarter point coefficients observed to set a point on that graph and estimate the appropriate value for α, which

would, in turn, enable calculation of the force in the member.

The lines in Fig. 1 are more closely spaced than the corresponding lines in Fig. 2, particularly in the low-frequency range. That is to say, there is considerably greater change in coefficients of curvature than there is in coefficients of amplitude for a given increment in force. The use of curvature measurements is in this respect conducive to greater experimental accuracy.

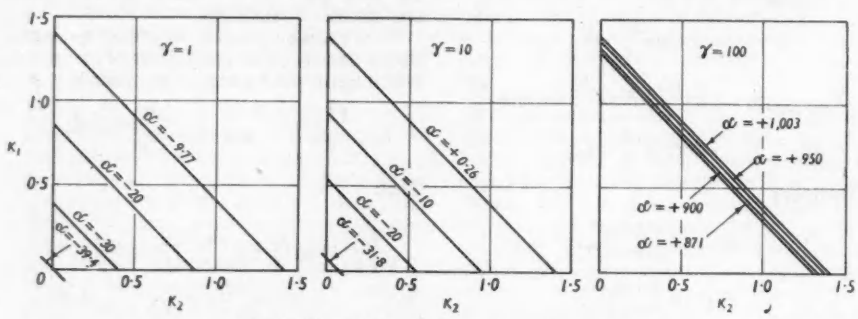


Fig. 2—K_1 and K_2 for various values of γ and α

If evaluation of test results were to require a multitude of graphs each for a definite value of γ, the process would be unwieldy and difficult. Fortunately, a major simplification is readily available. Since K_1+K_2 is dependent only on aL and bL, which themselves depend only on γ and α, it becomes possible to regard K_1+K_2 as a single entity, and relate it to γ and α by a family of curves.

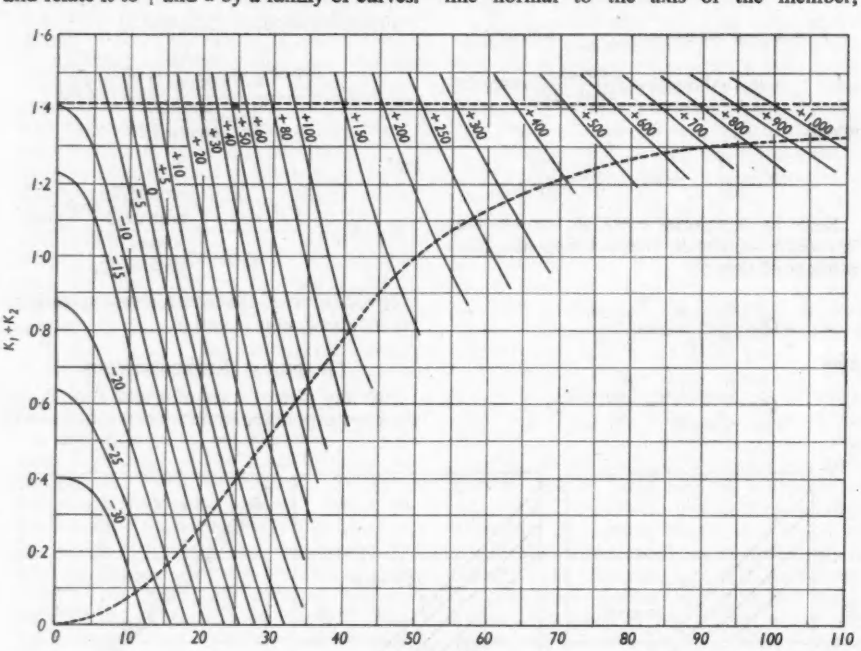


Fig. 3—Lines of constant α, where $\alpha=\left\{\frac{P-mk^2\omega^2}{EI}\right\}L^2$. Upper dotted line is appropriate to both ends pin jointed. Lower dotted line is appropriate to both ends fixed

The resulting family of curves (each for constant value of α) is shown in Fig. 3.

The stages in interpreting a set of test results are simplified to the following steps :—

(1) Establish the value of γ from the observed natural frequency.

$$=L^2\omega\sqrt{\frac{m}{EI}} \quad \text{or} \quad L^2N.2\pi\sqrt{\frac{w}{EIg}}$$

where

N=cycles per unit time.
w=weight per unit length.
g=gravitational constant.

(2) From γ and $\{K_1+K_2\}$ obtain intersecting co-ordinates on the graph, and read off the appropriate value of α by interpolation between the curves.

(3) From the value of α so established, calculate the value of P from the equation

$$P=\frac{\alpha EI}{L^2}+\frac{wk^2 4\pi^2 N^2}{g}$$

or

$$P=I\left\{\frac{\alpha E}{L^2}+\frac{4\pi^2\rho N^2}{g}\right\}$$

where

ρ=weight per unit volume of material of the member.

Special Cases

For the special case of symmetry about a line normal to the axis of the member, $Q_1=Q_2$, and $K_1=K_2$. In this case $A=0$.

For the special case of point symmetry, $Q_1+Q_2=0$, and $K_1+K_2=0$, and is satisfied when $B=0$. The general asymmetric mode is compounded of the two functions represented.

The fundamental mode, if symmetrical, must be governed by the former case, since at any given instant the deflections must be on one side of the neutral.

If, in addition to line symmetry, we impose a condition that both ends are freely hinged, there can be no end bending impressed by the vibration. Hence, Y'' is zero for $x=L/2$, or $x=-L/2$, and therefore

$$B\left\{-b^3\cos\frac{bL}{2}-a^3\frac{\cos bL/2}{\cosh aL/2}\cosh\frac{aL}{2}\right\}=0.$$

If $B=0$ there would be no vibration ; therefore, in general

$$(a^3-b^3)\cos\frac{bL}{2}=0.$$

Then for real values of both a and b,

$$\cos\frac{bL}{2}=0,$$

$$bL=\pi,\ 3\pi,\ 5\pi,\ 7\pi,\ \&c,$$

$$\alpha=\frac{\gamma^2}{\pi^2}-\pi^2 \text{ for primary,}$$

but generally

$$\alpha=\frac{\gamma^2}{n^2\pi^2}-n^2\pi^2 \text{ where } n \text{ is odd.}$$

If, on the other hand, symmetry is furnished by the condition that both ends are rigidly fixed, there can be no end gradient impressed by the vibration ; thus Y' is zero for $x=L/2$; therefore,

$$B\left\{-b\sin\frac{bL}{2}-a\frac{\cos bL/2}{\cosh aL/2}\sinh\frac{aL}{2}\right\}=0.$$

If $B\neq 0$,

$$b\tan\frac{bL}{2}=-a\tanh\frac{aL}{2}.$$

The lowest value of b which satisfies represents the primary mode.

The limits set by both ends freely jointed, and by both ends rigid have been regarded as ordinary limits for the preparation of Figs. 1 and 2. They are indicated in Fig. 3 by an upper dotted line for freely jointed ends, and a lower dotted line for clamped ends. Between these limits varying degrees of end rigidity obtain.

So far as Figs. 1 and 2 are concerned, the special cases, which are symmetrical, are represented by points where these upper and lower lines cross the diagonal axis of the graphs. The fact that extrapolating beyond these points has mathematical validity and, moreover, lines for constant α can be obtained for loads outside this range, indicates that negative end fixity will not invalidate the result. This might be occasioned by members beyond the connection vibrating in harmony.

Mention has not been made so far of the possibility of exciting a higher-frequency vibration than the primary, and at first sight the possibility of mistaking such higher frequency for the primary suggests a potential cause of ambiguity. The apparatus used for exciting vibration may limit the possibility of low frequency stimulation, so that it would be possible for the first indication of resonance to occur at a higher harmonic of the fundamental frequency.

Let us, just for demonstration purposes, consider a special case ; that of a pin jointed member will be characterised by sinusoidal mode patterns. The ends will be nodes, and there can be any number of nodes at equal intervals throughout its length. With one intermediate node, $K_1=-K_2$, or the sum of the coefficients is zero. Two intermediate nodes give $K_1=K_2=-70{\cdot}7$ per cent, or sum of the coefficients is negative. Only when the number of intermediate nodes reaches six will the sum of the coefficients repeat its fundamental value. This will represent the seventh harmonic, and the frequency will be in the order of forty-nine times the fundamental. It is suggested that a very approximate check of expected frequency would indicate this to be of higher

order. Otherwise, however, the misinterpretation in taking so high a frequency to be the fundamental would result in such gross over-estimation of tensile force that in most cases suspicion would be aroused.

This point will be rendered clearer by reference to Fig. 4, which shows extension of some of the curves from Fig. 3 into the range of the higher harmonics. It indicates the very considerable divergencies in frequency (γ), appropriate to any one curve, between successive repetitions of any value of (K_1+K_2) which lie within or are close to the "ordinary limits." It indicates, also, that any two curves passing through a point where (K_1+K_2) lies in this zone, are curves for greatly different values of force (α).

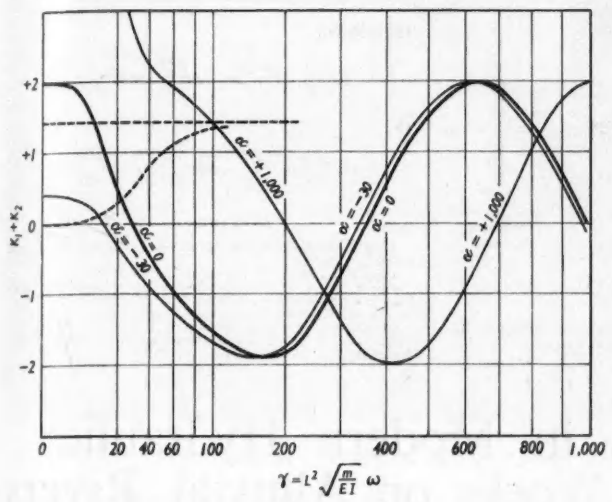


Fig. 4

Initial Bending

The considerations described might appear to carry a tacit assumption that the strut of tie is subject to no initial bending.

Any eccentricity of loading, or lack of straightness, which produces bending moments in a strut or tie will affect only its initial shape, and does not enter into the equations relating displacements from that position with time. Any bending moments imposed by the end connections in proportion to the change in end slope are rightly a feature of end stiffness, which the method has been designed to take into account in the most general way.

We determine only the resultant tension or compression, from which may be deduced the average stress, but have no indication of the stress distribution in a transverse section. If the force in the member is required in order to make a synthesis of forces throughout a framework, we have the gratifying assurance that the result has in no way been influenced by eccentricity.

The method is not applicable to beams carrying transverse loads, however, since such loads not only contribute to stress distribution, but add their own inertia forces, slowing down the vibration and modifying the mode. In certain instances where the load applied is uniform and accurately known it would be possible to include it in the value of weight per unit length, w (and mass per unit length, m).

Application to Prestressed Members

The scope of the present article is limited to members of uniform section. The postulation of constant moment of inertia requires that any reinforcing, whether pretensioned or not, must lie parallel to the axis of the member.

Within this limitation, prestress will not invalidate the precepts, but a distinction between two cases must be considered. If a concrete member is prestressed by a cable having continuous contact with the concrete, then clearly any increase or decrease in curvature is equal in the two materials. Over any elemental length of the cable there will be incremental restoring force equal to the product of tensile load, curvature, and length of the element. However, the equal and opposite force in the concrete due to prestress must weaken the restoring force in the corresponding elemental length of the concrete by the product of that force, curvature and length of the element. The two changes in restoring force will, therefore, be equal and opposite so that vibration characteristics remain independent of the prestressing force. Only the externally applied loads can affect net restoring force to modify vibration frequency, and the member may be regarded externally as a non-prestressed unit similar in material and geometry.

In other instances prestress is applied by cables passing through large ducts and having no contact with the concrete except at the end anchorages. The cables are not constrained to deflect with the concrete, and the forces due to changing curvature of the concrete are not accompanied by balancing forces in the cable. They decrease the restoring force in the concrete in just the same manner as when compression is applied externally, and slow the vibration similarly. It will be correct to regard the cable and concrete as independent units. Tests on the concrete will indicate the total load on the concrete. If it is practicable to vibrate the cable and determine its natural frequency its tension may be evaluated without recourse to additional measurements, since it closely approximates to the ideal long flexible wire, then

$$P \rightarrow \frac{\omega^2 L^2 m}{\pi^2} = \frac{4N^2L^2w}{g}.$$

An obvious practical difficulty in dealing with concrete is that its elastic modulus cannot be known so precisely as that of steel. A more obscure difficulty arising from the greater stiffness (i.e. the increased EI.) of conventional concrete construction is that much higher vibration frequencies than for steel are to be expected. This may render detection of the electrical signals from the strain gauges difficult without recourse to the complication of an oscillograph.

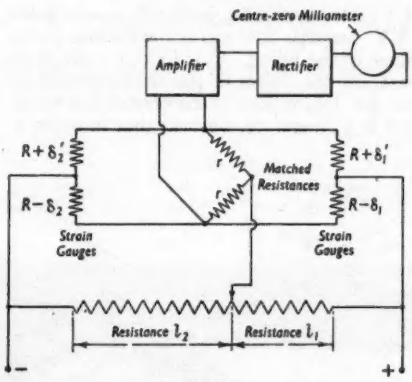


Fig. 5

Strain Gauge Circuit

If a pair of resistance strain gauges are mounted on opposite sides of the member, preferably as far from the neutral axis as possible, their differential resistance will be proportional to change in curvature at any instant. They may be connected as two arms of a Wheatstone bridge circuit and the out-of-balance current will be a measure of the change in curvature from initial datum. If this is done at the three appropriate points simultaneously the signals may be recorded either by oscillograph or if the frequency is not greater than about 50 c/s by photographic recording from a mirror galvanometer. A comparison of the traces would enable the ratios of the maximum curvatures to be obtained.

Since, however, it is the ratio, not the magnitude of change in curvature which is required, some simplification invites attention. The circuit indicated in Fig. 5 is one suggestion. The circuit would be brought into initial balance, using fine compensating adjustment for any inequality in the gauges and leads. During vibration of the member there will generally be a cyclical change of potential across the amplifier terminals which may be eliminated by one particular setting of the potentiometer. For instance, if the curvature at the left is less than that on the right, the strain gauges on the left would suffer less variation in resistance than those on the right. It will be necessary to inject into both upper and lower leads to the left an additional current to enable the left side gauges, despite their lower cyclical resistance change, to overcome the cyclical voltage across the amplifier terminals.

Using the notation for resistances as in Fig. 5, and putting $\delta_1'/\delta_1=\delta_2'/\delta_2$, it may be shown that when l_1 and l_2 have been adjusted for balance then

$$\frac{\delta_1}{\delta_2}=\frac{l_2(R+2l_1)+r(l_1+l_2)}{l_1(R+2l_2)+r(l_1+l_2)}.$$

If the gauges shown on the left represent those located at the centre of the member, and those shown to the right represent gauges at one of the quarter points, then $\delta_1/\delta_2=K$ and is a direct measure of one of the quarter point coefficients of curvature.

In order to avoid duplication of equipment and the need for simultaneous adjustment of two potentiometers, it is suggested the quarter point strain gauges placed along the same edge of the member be connected in series to form one arm of the bridge circuit, and gauges of double resistance used at the centre point. Then $\delta_1/\delta_2=(K_1+K_2)$ directly.

Examples of Interpretation

Final interpretation of the force in the member from test data has a potential simplicity which is illustrated by the following examples.

Example (*a*).—A flat tie, 8in by $\frac{1}{4}$in is 84in long, resonance occurs at 40 cycles per second and $(K_1+K_2)=1\cdot30$.

Putting all dimensions in inch, pound and second units :

$L=84$ inch.
$N=40\sim$/second.
$w=1\cdot70$ pound/inch.
$E=30\times10^6$ pound/inch^2.
$I=0\cdot2812$ inch^4.
$g=386\cdot2$ inch/second^2.

Then

$$\gamma=L^2N\,.\,2\pi\sqrt{\frac{w}{EIg}}=40\cdot5.$$

Referring to Fig. 3, the point of intersection of the co-ordinates $\gamma=40\cdot5$ and $(K_1+K_2)=1\cdot30$ corresponds to $\alpha=145$.

Using this in the equation

$$P=\frac{\alpha EI}{L^2}+\frac{wk^2\,4\pi^2N^2}{g}$$ (the second term of which is negligible)

$$\text{gives } P=\frac{\alpha EI}{L^2}=173{,}000 \text{ lb.}$$

corresponding to average stress=28,800 lb per square inch tension.

Example (*a*1).—Assuming the same data, except that $(K_1+K_2)=0\cdot90$, it is found that the point of intersection of the co-ordinates corresponds to $\alpha=107$, and using this value in the expression for P gives

$$P=\frac{\alpha EI}{L^2}=128{,}000 \text{ lb,}$$

corresponding to average stress=21,300 lb per square inch tension.

Example (*b*).—A standard 9in by 4in beam, 120in long between supports, is vibrated in its weaker bending plane. Resonant frequency=18 cycles per second and $(K_1+K_2)=1\cdot20$.

Putting all dimensions in inch, pound and second units :

$L=120$ inch.
$N=18\sim$/second.
$w=1\cdot751$ pound/inch.
$E=30\times10^6$ pound/inch^2.
$I=4\cdot15$ inch^4.
$a=6\cdot18$ inch^2.
$k=0\cdot82$ inch.
$g=386\cdot2$ inch/second^2.

Then

$$\gamma=L^2N\,.\,2\pi\sqrt{\frac{w}{EIg}}=9\cdot82.$$

The point of intersection of the co-ordinates $\gamma=9\cdot97$ and $(K_1+K_2)=1\cdot20$ corresponds to $\alpha=-4\cdot8$.

Therefore

$$P=\frac{\alpha EI}{L^2}+\frac{wk^2\,4\pi^2N^2}{g}=(-41{,}500+40) \text{ lb}$$

corresponding to average stress=6700 lb per square inch compression.

Acknowledgments

One of the incidental pleasures in preparing a technical article lies in the exchange of ideas and the altruistic assistance which the author experiences. The author of this paper is indebted particularly to T. L. Watkins, B.Sc., Grad. Inst. Physics, and H. A. Kirby, B.Sc., A.M.I.Mech.E., for many helpful suggestions and reading of the draft manuscript, and to Goodman's Industries, Ltd., and Dawe Instruments, Ltd., for information concerning available equipment.

Appendix

Equation 1.

Let y=deflection from neutral position of a point in the member, distant x along the member from any chosen origin, at time=t.

Then :

Elastic restoring force towards undeflected position per unit length

$$=EI\frac{d^4y}{dx^4}.$$

Force due to applied longitudinal tension P, towards undeflected position per unit length

$$=-P\frac{d^2y}{dx^2}.$$

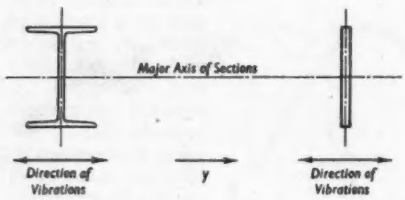


Fig. 6

Transverse mass-acceleration towards undeflected position per unit length

$$=-m\frac{d^2y}{dt^2}.$$

Increase in angular inertia-acceleration towards undeflected position per unit length

$$=mk^2\frac{d^4y}{dt^2dx^2}.$$

Now forces acting on unit length=mass-acceleration produced in unit length,

therefore :

$$EI\frac{d^4y}{dx^4}-P\frac{d^2y}{dx^2}=-m\frac{d^2y}{dt^2}+mk^2\frac{d^4y}{dt^2dx^2}$$

or

$$EI\frac{d^4y}{dx^4}-P\frac{d^2y}{dx^2}-mk^2\frac{d^4y}{dt^2dx^2}+m\frac{d^2y}{dt^2}=0.$$

Bibliography

Lord Rayleigh, *Theory of Sound*, Vol. I, Chapter VII (second edition), 1926.
Cole, E. B., *Theory of Vibrations*, London, 1950.
Senior, D. A., "Recording Signals from Resistance Strain Gauges," The Engineer, London, Vol. 197, Nos. 5121–4.
Yarnell, *Resistance Strain Gauges*, London, 1951.
Moore, H., "Vibration Generators, Ancillary Equipment and Applications," *Journal of the Institution of Radio Engineers*, Vol. XIV., No. 3, March, 1954.

Cut-offs in Modern Hydraulic Diversion Works on Alluvial Rivers

By S. LELIAVSKY, Ph.D., M.I.C.E., M.Am.Soc.C.E.

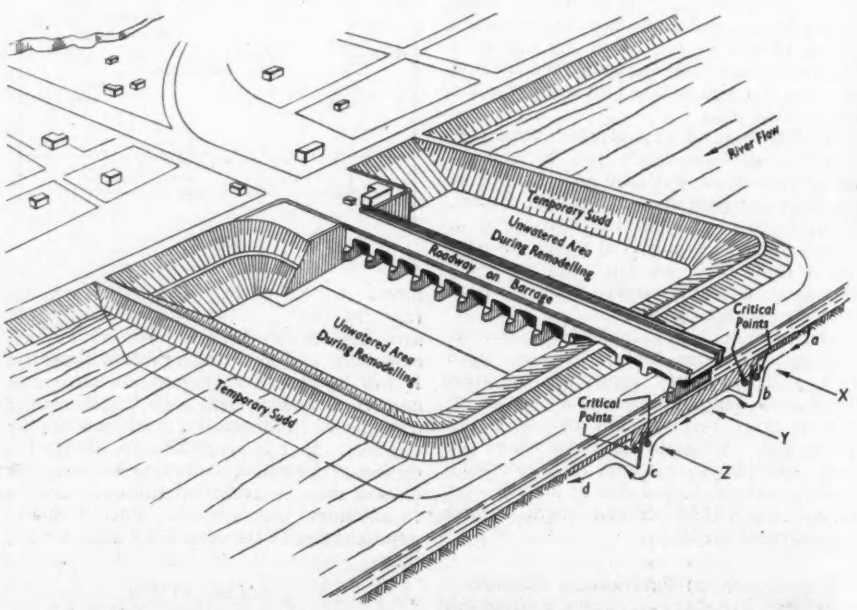
No. II—(*Concluded from page* 188, *August* 10*th*)

Though forever concealed below ground, the under structure of a hydraulic work, e.g. barrage, weir, lock, &c., is frequently more important—and might be more difficult to build—than the superstructure which appears above ground., The understructure may again be divided into two main constituent parts : the more or less horizontal floor and the vertical cut-offs placed beneath it, to render it more efficacious in counteracting the dangerous effects of enforced percolation. The construction methods employed in building the floor are those commonly used in other works, but the cut-offs are a sui generis *case, which is described in this article.*

(7) Particular Cases

WE have, thus far, implicitly assumed that seepage flow was perpendicular to the plane of the piling. This indeed is the usual case, for the object of the sheet piling is to cut the stream lines of the percolating water, and it is, therefore, obvious that in order to perform properly its duty this piling must be driven at right angles to the paths of filtration.

There are particular cases, however, when the trajectories of the percolating water particles are parallel to the piling; for instance, in problems connected with the strengthening of dam foundations, on alluvial



a, *b*, *c* and *d* flow of percolating water under normal conditions. *X*, *Y* and *Z* direction of seepage flow during remodelling works, near the crossing of barrage with the temporary sudd.

Fig. 16—Diagram showing critical seepage conditions during the remodelling of a barrage : note critical points of danger, as detected by experiment

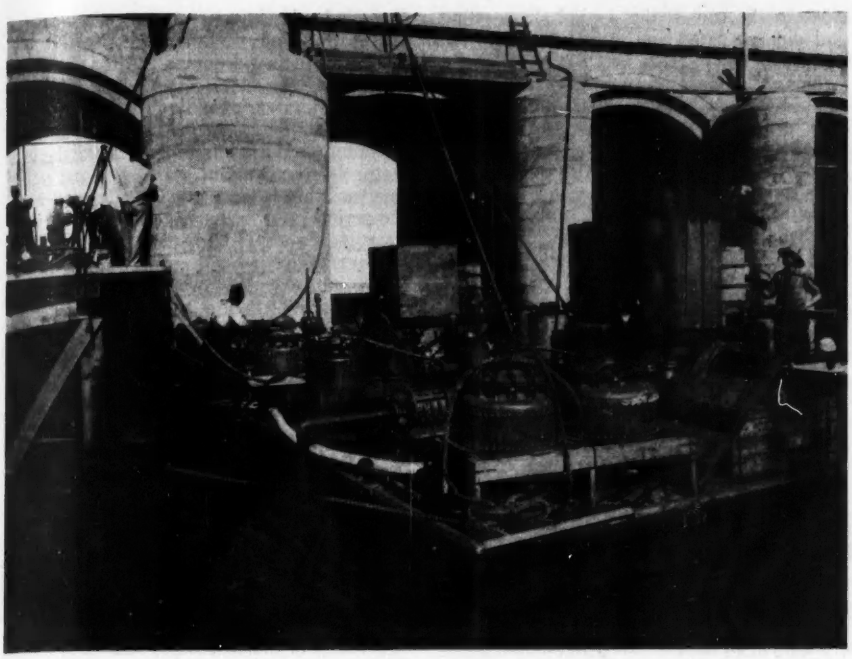


Fig. 17—Assiut barrage remodelling : injection in line with the sudd at the crossing with the barrage

rivers. Such critical conditions will occur at the point where the annual sudd—required for unwatering the area of the barrage intended to be strengthened during the works programme of a season—butts against the barrage (see " Critical Points " in Fig. 16).

This was one among the various problems which had to be solved in carrying out the strengthening of the Assiut and Esna barrages on the Nile. In addition to the particularly safe values of the creep coefficient, incorporated in the design of the sudds in the critical sections at their crossings with the old barrages, further precautions were then also taken to make assurance doubly sure.

With this object in view, the floor of the existing barrage was perforated, and emulsion injected, through pipes inserted into the bore holes, into the soil beneath it, thus constituting an early application (1934) of the principle of injected cut-offs. The credit for first suggesting this solution is due to the consulting engineers, Messrs. Coode, Wilson, Mitchell and Vaughan-Lee. The work was carried out by the François Cementation Company, who used injections of their own composition based upon the results of special tests made by them at Assiut. The soil treated in this manner did not constitute an entirely hard material—such, for instance, as that supposed to be produced by cement injections, after the cement is fully set—but was, nevertheless, sufficiently compact and impermeable, to create an efficient cut-off.

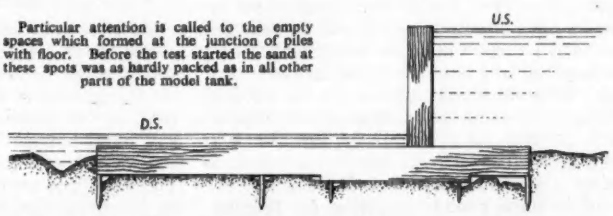

Particular attention is called to the empty spaces which formed at the junction of piles with floor. Before the test started the sand at these spots was as hardly packed as in all other parts of the model tank.
U.S.
D.S.

Fig. 18—Esna barrage remodelling percolation test, carried out at the Physical Department, Ministry of Public Works, in December, 1944

Part of the work was done under water. Timber scaffoldings were built for this purpose in the vents of the barrage to be so treated, while the main tackle, required for the injections, was floated on a pontoon. The photograph in Fig. 17 shows this work as carried out.

The grouting operation at Assiut barrage was wholly successful in achieving its intended objective, and was therefore resorted to again, some ten years later, for the remodelling works of Esna barrage, in which the same problem was met with.

In the several annual periods when the Assiut enclosures were kept unwatered, some significant observations were made on the nature of the percolation at the critical points near the crossing of the sudd with the barrage. Whilst at no time was this seepage bad enough to cause serious apprehension, it was, nevertheless, observed that whatever water percolated, at this spot, into the enclosure, came through the soil near the top of the piling, where it is caped by the concrete apron. These critical points are shown in Fig. 16 by crosses, the direction of the flow being as indicated by the arrows *X* to *Z*. This, case it is believed, represents almost a unique instance of percolation flow parallel to the piles, for usually seepage flow is at right angles to the plane of the piling (as shown in the same drawing by *abcd*) ; whereas here, it is parallel to the piling as shown by *X*, *Y* and *Z*.

In attempting an explanation, the author thought that the fact that the sand under Assiut barrage had been subject to enforced percolation for over thirty years, before the remodelling works began, should not be lost sight of.

Accordingly, when some years later he carried out a set of experiments in connection with the remodelling of Esna barrage, a special test was designed to investigate whether prolonged exposure to the effect of percolation could affect the consistency of the granular foundation. The results of this experiment are shown in the diagram in Fig. 18 and in the photograph in Fig. 19.

In interpreting these results, attention is called to the following. The conditions in a barrage are not exactly the same as in a tank

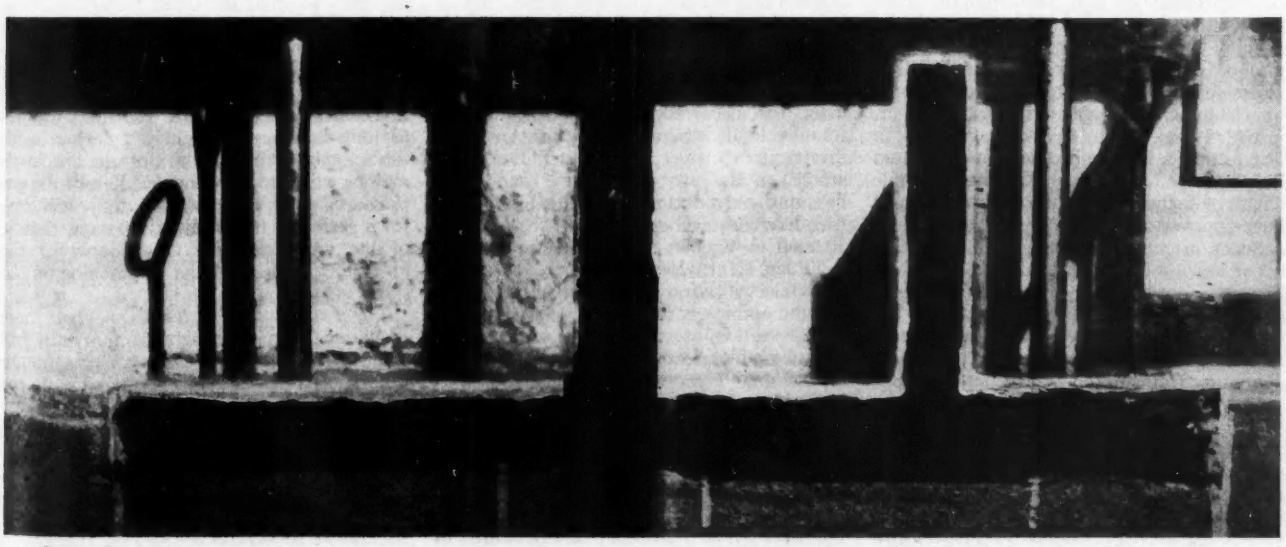


Fig. 19—Tank experiment on Esna barrage percolation

experiment for, as the soil beneath the apron settles, the foundation of the barrage moves with it, which causes an equalising effect on the soil consistency.

On the other hand, in the tank experiment shown in Figs, 18 and 19 the glass wall interfered with the free movement of the model. It follows, therefore, that local cavities could not have developed in fact to the same extent as they did in the model, but it appears from the test that, after a certain lapse of time, percolation of water must affect the compactness of the fill, at the critical spots of the foundation.

The duration of the test shown in Figs. 18 and 19 was two weeks. Introduction of dyes at the beginning of this period resulted in the usual, typical pattern of flow lines; but, when, after the two-week period had elapsed, the coloured water test was again attempted, all stream-lines terminated in the first cavity, close to the top of the second sheet piling, and did not extend any further beyond this point.

This experiment may possibly be considered significant, not only as yielding a physical explanation of the seepage observations in the enclosure of the Assiut barrage remodelling works, but also, as affording further support to Bligh's conventional assumptions, since the observed alterations in the compactness of the granular soil in the foundations of a barrage, must of necessity "suck in" the stream lines towards the apices of the inner angles of the creep polygon.

An intermediate set of conditions must then be reached, in which the flow lines are neither the perfectly smooth curves of the potential flow theory, nor Bligh's ideal rectilinear creep polygons with sharp angles, but a mixed pattern bearing some likeness to the characteristic trajectories of both.

Static in the Stars?

By C. E. R. BRUCE, M.A., D.Sc., M.I.E.E., F.Inst.P.

This may seem an odd article to appear in THE ENGINEER. *For at a first glance the subject appears to have little relation to engineering. In fact, however, Dr. Bruce, of the Electrical Research Association, turns out to be appealing to a stellar phenomenon to support a hypothesis about the manner in which the electrical fields associated with thunderstorms are created on earth. It is still true that the discussion is physical rather than technological. But physics and engineering are inter-related subjects. Electrical engineers, we think, will certainly be interested; and if mechanical and civil engineers may find here little engineering interest, many, probably, will have taken an interest, outside their professional work, in astronomical discoveries.*

ON March 18, 1755, in a letter to Dr. Lining, of Charles Town, South Carolina, Benjamin Franklin wrote: "I wish I could give you any satisfaction in the article of clouds. I am still at a loss about the manner in which they become charged with electricity; no hypothesis I have yet formed perfectly satisfying me." Just over 200 years later, the subject is still one on which there is considerable difference of opinion.

However, the writer would like to describe a series of observations which begins in the laboratory and ends in the atmospheres of the very large "cold" or red stars, which seem to point to static as the common origin for a very diverse group of phenomena including the electrification of thundercloud.

Laboratory Experiments.—Laboratory experiments made by P. E. Shaw[1(a)] in the 1920s showed that, in order to charge two bodies by rubbing them together, it is not necessary for the bodies to be of different materials. Two pieces of the same material will become oppositely charged when rubbed together, provided that the rubbing is asymmetrical. For example, if a limited section—say, 1cm length of one rod—is rubbed along the whole length of a similar rod, then the two rods will have opposite charges.

Such asymmetrical reactions obviously occur in wind-blown dusts and powders, and Shaw[1(b)] showed that these also become charged, even though the reactions are limited to those between pieces of the same material. Furthermore, he showed that the charging effect is of the same order of magnitude with cold dry ice particles as it is with sand.

Terrestrial Electric Storms.—In view of the asymmetry of the effects we may suppose that on an average larger and smaller particles will become oppositely charged, and there is some experimental evidence to support this supposition. Their separation in a gravitational field will then lead to the setting up of an electric field in a cloud of wind-blown particles. That electric fields can be set up under such circumstances is well known, and in sand storms and in the ejectamenta from volcanoes they can lead to the breakdown of air at atmospheric pressure. Sir George Simpson,[2] when meteorologist with Captain Scott's last Antarctic expedition, likewise observed that driven snow in blizzards gives rise to marked electrical effects, and in these conditions, as in the thundercloud, the field is with few exceptions positive—that is, the lower charge is negative.

It is significant that during a recent discussion of thunderstorm electrification at the Royal Meteorological Society, two of the most active observers both expressed themselves as being strongly of the opinion that no electrical effects are to be anticipated in thunderclouds until the anvil shaped top of cirrus cloud appears. This forms at about −30 deg. Cent. and at a height of 30,000ft to 40,000ft, and is composed of dry ice crystals. This view as to the critical requirement for occurrence of electrification in thunderclouds is supported by the American investigators[3] who recently made a mass attack on the problem. They found that lightning only occurs when the top of the thundercloud reaches heights of the order of 30,000ft to 40,000ft and temperatures below −20 deg. Cent. However, the actual details of the electrification process are still in doubt, and the opinion is still strongly held that it is the deposition of supercooled water on ice particles which leads to much of the charge separation. The observations in the laboratory, as well as in sand and thunderstorms, would, however, appear to indicate the adequacy of static electrification due to asymmetrical impacts to explain the phenomena.

Long-Period Variable Stars.—And now to the stars. The "surface" temperatures of stars range from 1500 deg. or 2000 deg. K up to about 30,000 deg. K and even higher. However, it is the low temperature end of the range in which we are interested for the present, and in particular the red, or long-period, variable stars. The light from some of these stars varies periodically in intensity by a factor of as much as 10,000 between maximum and minimum, though the average factor is round about 100. The period of this variation is usually a few hundred days, the period most frequently observed being in the region of 250 to 300 days. The cause of this variability is not known at present, but the writer has put forward the suggestion that the prime cause is the occurrence of "thunderstorms" in the stars' atmospheres.[4(a)] For these stars all have very extensive atmospheres outside their surfaces or photospheres, some of which would easily contain the earth's orbit.

The temperatures of the atmospheres of these red stars are, at minimum anyway, lower than even their surface temperatures of 1500 deg. to 2000 deg. K. Indeed there would appear to be nothing to prevent the temperatures of these outer atmospheres from falling to values at which the electrical conductivity will be sufficiently low to allow of the generation of electric fields.

Freezing in Stellar Atmospheres.—At these low temperatures a number of materials, such as metallic oxides, hydrides and carbides, will have solidified out of the atmosphere. The existence at minimum phase of such solid or liquid particles had indeed already been deduced, as they offer the likeliest explanation to account for a large proportion of the diminution of the stars' light. To a large extent the light of the star remains of the same quality, but there is just less of it—it is veiled by the cloud of particles.

Generation of Electric Fields in Stellar Atmospheres.—The solid particles in the gas will be subject to the violent impacts required for the generation of static, since it is known from spectroscopic observations that the gas velocities in the stellar atmospheres reach values of the order of 10km per second. The conclusion would therefore appear to be inevitable that there will be considerable generation of static and of electric fields in these stellar atmospheres, and that these last will ultimately build up until discharges occur, since as we have seen, the temperatures are probably too low to allow of appreciable conductivity. The ensuing lightning flashes will, of course, last much longer than the fraction of a second of terrestrial lightning flashes. Whereas the latter are about 10km in length, the stellar discharges may be from 100 million kilometres to 1000 million kilometres long, from the observed extent of their atmospheres. They may therefore be expected to last from 10,000,000 to 100 million times as long as terrestrial lightning flashes, since the velocity of propagation of the discharge may be expected to be independent of the gas pressure.[5] In other words, they will last for a period of the order of 100 days, that is, of the order required to account for the observed duration of the brightening of the star's light.

Effect of Stellar Discharges.—When these discharges occur the light of the stars will change. The effect will then be just as though a candle flame suddenly began to emit the light of an electric spark. Bright emission lines will appear in their spectra and this is just what happens. Indeed, it is the appearance of these bright lines in their spectra which leads to their detection as long-period variable stars. It has so far proved impossible to explain the sudden appearance of these bright lines originating in such surroundings. The occurrence of electric

discharges in these stellar thunderstorms, that is, the sudden transformation of electric field or potential energy into that of excited atoms having temperatures far above that of their surroundings, offers a way out of the difficulty.

The manner of the appearance of these bright lines and their variation during the outbursts also agrees with their "thunderstorm" origin.[4(b)] The rate of generation of the atmospheric electric fields will increase with the gas pressure and with the force of gravitation, so that breakdown may be expected to be initiated relatively low down in the star's atmosphere. The discharge will then be propagated mainly outwards. The light from it will therefore be subject to less and less absorption by the overlying atmosphere as the outburst continues, and only towards its end will the spectrum lines shine out more or less unaffected by this absorption. This is in fact what is observed to happen. Groups of lines, such as the Balmer series of hydrogen, and smaller groups, or multiplets, in the iron spectrum, for example, have definite intensity ratios in laboratory spectra. When the bright lines first appear in these stellar spectra, around the time of minimum light, the relationships between these line intensities are found to be considerably modified by the differential absorption to which they are subjected on the way out by the molecules of metal oxides, &c., in the atmosphere. This mutilation of the customary intensity relationships gradually decreases as the outburst continues, until, towards its end, their ratios approach those observed in the laboratory.

Discharges as Energy-Pumps.—There is another characteristic of these long electrical discharges to which the writer first drew attention in relation to the lightning leader-stroke,[4(c)(d)] which may also be expected to play an important role in these long stellar electrical discharges. The discharges act as short-circuits of atmospheric electric fields, and hence as energy-pumps, so to speak, liberating in the upper regions of lower density some of the energy generated lower down in the regions of relatively high density. In a lightning flash, for example, the same thing occurs. The highest current flows at the beginning of the return-stroke just above the earth's surface and about 5km to 10km away from the point in the thundercloud where the maximum rate of generation of electric field occurred. In an earlier article[4(c)] it was pointed out that this effect may probably explain the gradual increase in excitation of the radiating atoms of gas during a nova outburst. In quite a similar way in these smaller stellar outbursts—smaller that is, compared with the nova outburst—the degree of excitation of the atoms will also increase as the discharge is propagated outwards into regions of lower density. This is just what is observed in this case, too, as it is in the nova outburst.

Combination-Spectra Stars.—In some of these stars the nature of the light varies to such an extent at different phases of the outburst that the phenomena have usually been assumed to originate in a complex system comprising a pair of stars, differing widely in type, associated with an extensive diffuse nebula. The large red star was believed to be accompanied by a small hot "companion" star, which was introduced to account for the light emitted during the early stages of the discharge. The nebula was introduced to account for the light of higher excitation emitted during the later stages of the discharge. These stars are said to possess combination or composite spectra. The nebular spectrum, of high excitation, is observed to follow the "companion" spectrum fairly regularly after periods which range roughly from 100 to 200 days in different stars. One observer[6] summed up his description of the sequence of the two different kinds of spectra by concluding that it is just "as though they occurred as a consequence of the propagation of running waves over an extended medium." On the proposed discharge theory that is just what is to be expected, the "running waves" being waves of electrical excitation.

Conditions Required for Long Discharges.—Some years ago, when putting forward a new theory of the initiation and propagation of lightning leader strokes, the writer showed that that theory would explain the very wide variation observed in lightning currents.[4(a)] It may be mentioned in passing that the theory also showed that the range of protection of a lightning conductor would increase with the current in the flash[4(f)], whereas until then it had been assumed that this protective range would depend solely on the height of the lightning conductor. It was shown that for a lightning flash to occur two things are necessary. First, an average electric field between the two charges in the cloud, or between one of these charges and its image in the earth, sufficient to maintain the process of arc conduction in the leader stroke when once it is initiated, i.e. an average field of the order of 10 to 100V/cm; secondly, in that relatively low average field there must exist a field concentration, such as is caused by a tall earthed building on the earth, or an elongated volume of space charge in the cloud, sufficient to cause the transition in the St. Elmo's fire or brush discharge, from a field-maintained corona discharge, to a thermally-ionised column of arc discharge. When this transition occurs the discharge becomes self-propagating, so to speak, and bridges the gap. The smaller the field concentration the longer will the initiation of the self-propagating discharge be delayed, and the greater will the current in the discharge be when it does occur. The same may be expected to apply in all long purely atmospheric discharges resulting from fortuitous variation in the distributions of space charge. The longer the initiation of the discharge or discharges is delayed in the stellar atmosphere, however, the greater will be the cooling of the atmosphere after the previous outburst, and the greater also will be the amount of matter solidified out of the atmosphere during the minimum phase. This will have two effects. It will cause a greater dimming of the star's light, and hence a lower light minimum, and a greater increase in the average electric field, and hence a greater outburst when the discharges do occur. Besides accounting for the irregularity of the period and amplitude of the variations observed in these stars generally, it may be, therefore, that these considerations will also explain some observations made on one of these stars which possesses a combination spectrum. The star is in the constellation Aquarius, R. Aquarii, and Merrill has pointed out[7] that in a series of pulsations of this star around the early 1930s very marked dimming of the main red star was associated with extra bright outbursts of the "companion star" or discharge spectra.

Evolution and Chemical Composition of the Stars.—The theory has a bearing on two problems of major interest in astronomy, namely, those of the nature of the evolutionary process in these red giant stars, and the question of the uniformity of the chemical composition of matter throughout the universe, since the atmospheres of these stars are one of the few places where there is generally considered to be a departure from this uniformity.

Stars can be arranged in a series having decreasing "surface" temperatures until we arrive at temperatures of the order of 3500 deg. to 4000 deg. K, i.e. at temperatures at which the freezing out of hydrides and carbides and carbon itself from their atmospheres begins. Below these temperatures the sequence apparently trifurcates, the three branches being differentiated by the different materials which contribute to the absorbing molecules in their atmospheres. One group—the carbon stars of Classes R and M—shows the bands produced by the C_2 and CN molecules; another—the titanium stars of Class M—shows mainly bands of titanium oxide; while in the third—the zirconium stars of Class S—the titanium oxide is replaced by zirconium oxide. These differences are usually attributed to actual differences in the chemical constitution of the stars' atmospheres. The writer, on the other hand, has suggested that the difference is mainly one of the average physical state of the atmospheric material external to the stars' photospheres or "surfaces."

As the temperature of this atmosphere falls during its evolutionary process, the first molecules to form will be those of C_2 and CN. At still lower temperatures particles of carbon, carbides and hydrides will be formed, so that the bands of C_2, for example, will disappear from the spectrum. The carbon bands will be replaced by those of molecules that associate at lower temperatures, such as zirconium oxide, which will begin to appear at temperatures of the order of 3000 deg. K. However, in its turn zirconium oxide will freeze out and become solid particles at temperatures around 2500 deg. K, and its place will be taken by the vapour of titanium oxide and others which form around this temperature. Titanium oxide will remain in the vapour state, and give rise to bands in the star's spectrum, until it in turn freezes out at temperatures around 1600 deg. K.

Thus at any one stage in the evolution of the outer atmosphere of a star, the oscillations in temperature of that atmosphere, due to the occurrence of discharges followed by a period of cooling and field-generation, will occur throughout a given range. It would seem, therefore, that this range for any one star at any one time in its history can quite well be appropriate for the appearance in its spectrum of each of three main sets of molecular bands in turn as the star gradually evolves. If, for example, during its evolutionary process the average temperature falls, then the carbon molecules will disappear, having become particles of carbon, which will no longer be vaporised to any appreciable extent by the discharges when they occur. The carbon bands will be replaced by zirconium oxide bands, until the average temperature falls so low that the solid particles of zirconium oxide are no longer vaporised by the discharges, and only titanium oxide bands will appear throughout the cycle.

There is one piece of evidence which seems to offer support for this view. It would appear quite possible on the view now proposed, that stellar atmospheres may exist such that at minimum only titanium oxide bands appear in their spectra. However, the general heating of the atmosphere by the outburst of discharges may be so great as to raise its temperature to such a value that the titanium oxide vapour is dissociated and the zirconium oxide particles are unfrozen or

vaporised. The star's spectrum will then cease to show the bands of titanium oxide, but will instead show zirconium oxide. In other words it will be changed from Class M to Class S by the outburst.

Now in fact stars do exist which occasionally show this spectral change as the result of specially great outbursts, i.e. when they reach what is for them an exceptionally bright maximum, and consequently a high average atmospheric temperature. The star in the constellation Cynus, χ Cygni, is one of these stars. On the present widely held view that the change from Class M to Class S really indicates a change in the chemical composition of these stellar atmospheres, it is very difficult to see how one and the same star can show the two types of spectra. It would thus seem that these stars are not necessarily in conflict with the general uniformity of chemical constitution of matter observed through the universe, as they are generally considered to be, nor do they necessarily indicate a trifurcation of the evolutionary sequence, in quite the way they are generally regarded as doing.

Advantages of Wide Views.—The writer hopes he has demonstrated the advantages to be derived from taking wide views. In the present connection, for example, an earlier familiarity with the characteristics of the electric arc probably helped towards the recognition of the lightning leaderstroke as a lengthening column of arc discharge. Certainly the study of that discharge, in which the leaderstroke's characteristics are made more manifest, hastened the discovery that the breakdown to arc-like characteristics is also complete during the leaderstroke phase of the long laboratory spark discharge.[4(d)] This remained a prediction or deduction from the earlier work on the lightning discharge, until it was verified experimentally in the laboratory by Komelkov some years later.[8] The investigations on the lightning discharge in turn led to renewed interest in certain aspects of the arc discharge, the further investigation of which has led to new light being thrown on the characteristics of that discharge. For example, the interest in the transition from the glow, or corona, to arc discharge fostered by the new theory of the leaderstroke, led directly to the discovery that the cathode of the hydrogen arc can be in the glow state,[4(g)] whether the copper cathode is water-cooled and solid or molten, and that arc-like conditions can be set up in laboratory discharges in times of the order of a microsecond.[4(h)] It also led to a purely thermal theory of the transition from the diffuse low-current arc to the concentrated high-current arc.[9]

In the present and earlier notes an attempt has been made to show that a very wide extension of the field of electrical discharges in gases may be effected by a reassessment of many astrophysical phenomena from the point of view now proposed. In the letter to which reference was made at the start of this note, and immediately before the quotation there given, Benjamin Franklin quoted a passage from the "Minutes" he kept of his experiments in which he had enumerated twelve particulars in which the "electrical fluid agrees with lightning." He continued: "The electric fluid is attracted by points. We do not know whether this property is in lightning. But since they agree in all the particulars wherein we can already compare them, is it not probable that they agree likewise in this? Let the experiment be made." The last sentence is surely one of the most pregnant in the history of electricity. In suggesting a step of still greater ratio in the field to which ideas on static may be applicable, the writer unfortunately cannot end this note on the intercomparison of the two fields with a similar suggestion. He can only suggest that the observations made in some branches of the wider field of astrophysics should be studied from the new point of view, and hopes he has demonstrated that the first fruits of so doing are at least promising.

REFERENCES

[1] Shaw, P. E.: (*a*) *Nature*, 1926, 118, 659; (*b*) *Proc. Roy. Soc. A.*, 1928, 122, 49.

[3] Simpson, G. C.: "British Antarctic Expedition, 1910-13," *Meteorology*, 1, page 306.

[3] "The Thunderstorm" (Ed. by H. R. Byers), U.S. Dept. of Commerce, Washington, 1949, page 89.

[4] Bruce, C. E. R.: (*a*) *Observatory*, 1955, 75, 82; (*b*) *Phil. Mag.*, 1955, 46, 1123; (*c*) *Nature*, 1941, 147, 805; (*d*) *Proc. Roy. Soc. A.*, 1944, 183, 228; (*e*) *El. Review*, 1953, 153, 1203; (*f*) *I.E.E. Journal*, 1943, 90 (I), 521; (*g*) *Nature*, 1948, 161, 521; (*h*) E.R.A. Report, Ref. L/T 205, 1948, "The Characteristics of Short Discharges" (with W. Nethercot).

[5] Schonland, B. F. J.: *Proc. Roy. Soc. A.*, 1938, 164, 132.

[6] Aller, L. H.: Pub. Dom. Ap. Obs., 1954, 9, 353.

[7] Merrill, P. W.: *Spectra of Long-Period Variable Stars*, Chicago, University of Chicago Press, 1945, page 84.

[8] Komelkov, V.: Dok. Akad. Nauk., U.S.S.R., 1947, 68, 57.

[9] King, L. A.: *Nature*, 1954, 174, 1008.

Hydraulic Self-Aligning Seating

By A. C. CARTER

Indications of strength of materials, particularly those of non-homogeneous structure, such as concrete, can be influenced by the conditions under which a test is performed. The verified performance of the testing machine is not necessarily a criterion of the principal force applied to the test specimen. In the routine testing of such materials it is important that comparisons may be made between unrelated specimens. It is not less important that strengths indicated by alternative testing machines should have a common basis of accuracy. One prevalent cause of inconstancy is examined, and means are suggested whereby friction and its consequent effect upon extraneous forces may be reduced.

THE customary method of determining the compressive strength of concrete and cement is to submit carefully prepared cubical samples to an increasing load. The load at which the sample fails, divided by the cross sectional area, is taken as an indication of the quality of the material. It is known, however, that the properties of different parts of the specimen vary. Variation in strength is usually accompanied by variation in the elastic modulus which increases with strength.

There are two distinct methods of transmitting the load to the sample. The load can be transmitted through fixed platens allowing no lateral or rotary movement. Alternatively, the load may be applied so that errors or changes in parallelism of the specimen are automatically compensated by a self-aligning seating. It is suggested that the mechanics of the two methods are as follows. Method (A) with fixed platens, the strain will be the same in all parts of the specimen and the stress will, therefore, be greater where the elastic modulus is greater. Thus, the stronger parts of the specimen will be subject to a greater stress than the weaker, and the strength of the specimen will correspond to the sum of the strengths throughout its cross section.

Method (B) with self-aligning platen, the stress will be the same in all parts of the specimen which will fail when the stress reaches the failing strength of the weaker parts of the specimen. It is customary to place the test cube on its side, that is to say, the load is not applied to the top of the cube as cast. As presented to the load, one-half of the specimen is usually weaker than the other. Therefore, if the load is truly axial, opposite halves will be subject to equal loads, and the specimen will fail when the average stress reaches the failing strength of the weaker half.

In regard to Method (A) the platens must be rigid laterally and parallel to one another and the operative faces of the specimen must be mathematically plane and parallel. The faces of a cube as cast will seldom be perfect enough in form to comply with these essentials, and a machining operation would be required. Due to the tendency of incipient cracks to occur in the faces of the specimen as a result of grinding, this operation is by many authorities considered inadmissible. The difficulties involved in implementing the test with fixed platens are, therefore, considerable.

In the case of Method (B) the self-aligning platen must be free to move continually throughout the test to failure. But it has been found that the normal type of ball seating specified in B.S. 1881 does not afford freedom of movement at the loads required for testing.

Certain reasons favour the use of the self-aligning platen: B.S. 1881, 1952, specifies this method; it is in general use and it has advantages in respect of time saving. Provided the test cubes conform to B.S. 1881, the operative surfaces are satisfactory for test. Of the two methods it is not possible to say which gives the truer indication of strength. Arguments can be brought forward giving preference to either. On the one hand the method which indicates a sample strength similar to that of the mass from which it is sampled would seem to be preferable. On the other hand, preference might be given to the method which, although giving a different strength to that of the mass, provides greater accuracy in comparisons between samples and between different testing machines.

When the force is compressive the aligning bearing usually takes the form of a ball-seating which, assuming friction absent, can transmit a force only in one direction. The behaviour of such a device has been examined by A. G. Tarrant in papers recently published in THE ENGINEER,* which evaluate the limitations of ball seatings. In terms of practice the friction in a 10·7in diameter ball seating, which is a representative size of this component used in 200-ton compression test machines, will cease to follow a linear relationship with respect to the load at higher loads than approximately 50 tons. This figure is based on a maximum stress of 1000 lb per square inch in the seating, which can be achieved only by the use of special high polar grease between accurately finished spherical surfaces. In any such bearing the limit as a self-aligning member is reached when the lubricant film breaks down, when the coefficient of friction rises to about 0·6. The behaviour of the lubricant film in this case is not analogous to that in a rotating bearing in which the film is constantly maintained by the revolving shaft. In a static bearing the lubricant is being

* THE ENGINEER, August 20 and December 10, 1954.

constantly expelled without replenishment.

It is therefore evident that what at first sight appears a simple mechanical device is in reality an unreliable one if used without regard to its limitations. In testing machines it is important, not only that errors introduced by the aligning device are known; there must also be a high degree of uniformity of performance between apparatus of the same class so that results of unrelated tests of similar materials may be compared It will be agreed that in the testing of a

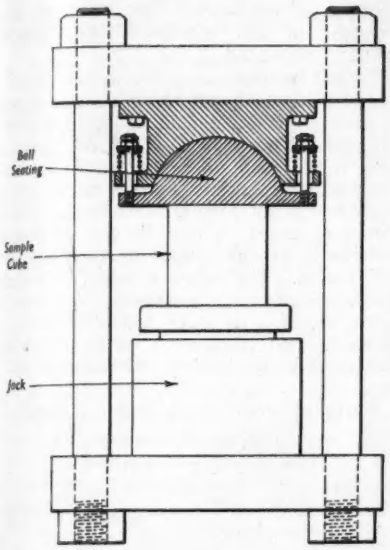


Fig. 1

concrete cube no force other than the axial force should be applied. The degree to which extraneous forces are present depends upon a number of factors, not least of which is the degree of friction developed in the aligning device. It is therefore reasonable to suppose that reduction of friction here will achieve greater accuracy in the result.

To this end two methods have been investigated recently—(1) the ball seating (Fig. 1), and (2) an alternative device known as a hydraulic seating (Fig. 2). A. G. Tarrant shows the way in which the ball seating can

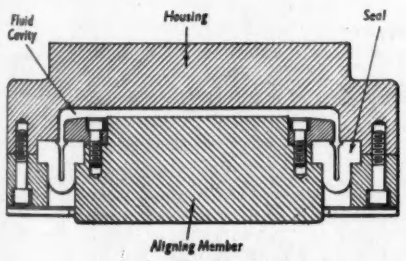


Fig. 2

be improved. In practical terms, a ball seating to perform satisfactorily at loads of up to 200 tons would be some 18in in diameter with the spherical faces machined to a high degree of perfection and lubricated with high polar grease. The apparent alternative of forcing lubricant continuously into the seating is not only undesirable owing to cost and complication involved, but it is not, in fact, possible if the function of this particular type of seating is to be preserved. To enable oil to be introduced there would have to be some clearance between the hemispherical faces, otherwise impossibly high pressures would be required. If sufficient clearance could be allowed, the central point of the platen face would be free to move laterally and the fixed central point is a feature of the hemispherical seating. The provision of an 18in diameter ball seating introduces other problems—for example, a larger load frame would be required to accommodate it, and further the head of the testing machine which houses the socket element of the seating must be rigid enough not to distort measurably under load, as this would tend to destroy the spherical form of the seating and thus disturb the even distribution of stress in the bearing. The limitations of the spherical seat as applied to this particular test suggest that this form of aligning bearing is unsuited to this work unless certain criteria are authoritatively specified as to its design and performance.

Some form of hydraulic seating was thought to offer a possible solution to the problem. Experiments with hydraulic rams, short in comparison with their diameters, showed some promise; but it was clear that existing forms of hydraulic gland or packing limited the angle to which the seating could be displaced. Further, it was considered essential that the fluid should be hermetically enclosed so that in no circumstances could a leak develop because a reduction in volume of fluid would eventually result in internal contact between the two elements of the seating.

A design was prepared to meet the following requirements:—(1) That the friction coefficient should be small in relation to the load; (2) to be self-contained; (3) to be suitable in use by semi-skilled or unskilled labour; (4) that no significant maintenance work be required; (5) the overall diameter and height of the seating to be such that it could be installed in any existing machine used for compressive strength tests, and preferably to occupy no more space than existing spherical seatings; (6) that the device should be constructed of readily available materials which could be fashioned without special machine tools; (7) that for the purpose of initial experiment the device should function satisfactorily at loads of up to 200 tons; (8) that the aligning member should provide angular movement or tilt up to 5 deg. from horizontal; (9) that the working pressure should be about 6000 lb per square inch, as the stressed areas thus involved would be of reasonable proportions; (10) that the cost should be comparable with that of the normal kind of spherical seating.

This alternative device, known as a hydraulic self-aligning seating (Fig. 2), has been developed and submitted to a series of tests carried out over a period of some eighteen months. The assembly consists of three main parts: (1) the housing, (2) the platen, and (3) the flexible annular hydraulic seal. Water has been found suitable for the hydraulic element. The annular seal is a "U" section; the extremities of the "U" terminate in heavy reinforcing rings which fulfil a similar purpose to those used in a motor tyre. The beads thus formed are held in pressure-tight grooves in the housing and platen respectively, which are therefore joined together flexibly and hermetically. Angular deflection of the platen causes the seal to distort so that one member of "U" lengthens as the other shortens, thus producing a rolling action.

A full-size working model was made, having a platen of 10in effective diameter and cotton reinforcement of the seal. Using air-free water as the hydraulic fluid, an exploratory test under light load indicated immediately a source of weakness. The cotton reinforcement of the natural rubber hydraulic seal failed at 28 tons load. The hydraulic pressure at this load was 900 lb per square inch. The force developed in the cotton was calculated to be 700 lb per linear inch of the circumference of the seal. Eight layers of cotton were used, laminated in the manner shown in Fig. 3, so that the force in each layer was approximately 87 lb per inch. Although some improvement in strength might be obtained by a different grade of cotton fabric, it was considered that such means would not offer complete solution, because in order to support a

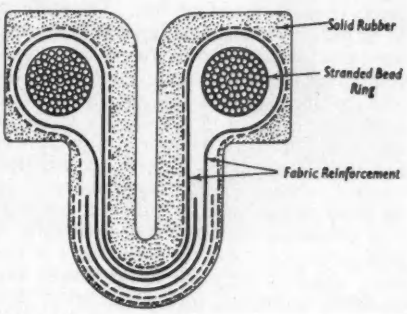


Fig. 3

working load of 200 tons the ultimate strength of the seal would have to be about ten times that already obtained.

The use of one of the relatively new synthetic fibres instead of cotton was a fairly obvious choice. Nylon fabric was readily available and after rubber-proofing difficulties had been overcome a number of hydraulic seals were made. The first seal produced withstood a load of 70 tons, but improvement in technique enabled the load to be increased to 100 tons. This unit, labelled model "A," was used for a series of tests on concrete and tests of apparent friction requiring the use of loads not exceeding some 40 tons. Because no more layers of nylon fabric could be accommodated in the space provided, and rather than increase the annular space, it was decided to replace the square woven fabric with weftless nylon cord, which would be laid in a position in a manner similar to that of a motor tyre. By these means a maximum benefit of the strength of the reinforcement would be obtained. A number of

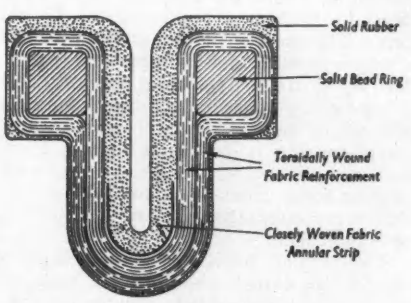


Fig. 4

succeeding units were made in this fashion with weftless nylon fabric, again using the method shown in Fig. 3, but with solid bead rings. All these sealing units failed, due to leaks through the crown of the seal. The reason for this was found to be insufficient rubber on the inside surfaces of the seal. This was largely due to attempts to pack as much fabric as possible in the available space to the exclusion of solid rubber to act as an impermeable barrier to the fluid.

The method of laminating the reinforcing fabric (Fig. 3) had been used in all the attempts so far, and on closer investigation

it was seen that some 30 per cent of the stressed area of the seal was occupied by the ends of successive layers which contributed little to the strength of the assembly. A means, therefore, was sought to arrange that each of the strands or filaments of fabric should support a proportion of the load. This was finally achieved by winding the reinforcement in the form of nylon tape, 1in wide, in toroidal fashion (Fig. 4). This method avoided the wastage of space by the ends of separate layers of material. Four layers of tape were wound, giving eight layers to each limb of the seal. The problem of providing an adequate layer of rubber on the inner surface was overcome by closely controlling the mean length of the reinforcement between beads and by inserting a single continuous strip of closely woven fabric at the inner surface of the crown, as shown in Fig. 4. These two factors allowed the uncured rubber entering the mould to force the fabric to the outer surfaces of the mould, thus permitting the solid rubber to form a continuous layer over the inner faces of the seal. The first unit made to this design was successful and after a preliminary test at 200 tons the device was submitted as model " B " to a further series of tests involving the application of loads up to 180 tons. This technique was adopted and the next seal produced, labelled model " C," behaved satisfactorily up to 200 tons load, and it was decided to increase the load to failure. This was done on a 500-ton testing machine. A small leak appeared at 245 tons, which disappeared when the load was reduced. The load was then increased up to 270 tons before the leak reappeared and the test was discontinued. On examination the rubber lining of the seal was found to be imperfect at the point where the leak appeared. The reinforcing fabric was undamaged.

The area of the annulus containing the seal was 0·35 of the area of the platen. The force to be contained by the seal at 200 tons was therefore about 70 tons. The mean circumference of the seal was 31in, hence 2·25 tons per inch was developed. With eight layers of 1in wide nylon tape the load taken by each turn was approximately 0·28 ton. From tensile tests of the nylon tape the breaking load was found to be 0·5 ton minimum and the breaking strain 18 per cent to 20 per cent. At 200 tons load the strain developed from bead to bead was approximately 12 per cent. The grade of natural rubber used had a tensile strength of 4000 lb per square inch, but at the strain to which it was subjected (12 per cent) it contributed little to the total strength of the seal. It is of interest, however, that the rubber lining to the inner surface of the seal was subjected to high compressive forces from direct contact with the fluid at pressures sometimes exceeding 6000 lb per square inch.

The aligning device was developed principally for compressive strength tests of concrete, but it is equally suitable for tests of other materials in which it is important to avoid localised stress in the sample. Since the fluid pressure is directly proportional to the load, measurements of fluid pressure by means of, for example, a Bourdon tube gauge may be used as an indication of the load being applied. Also, due to the flexibility of the seal it is possible to apply load to a sample by increasing the volume of the fluid by means of a high-pressure pump. In the particular design described above the extent of axial travel of the moving member is restricted to about ½in, but could be increased by suitable modification. In this form it could be used as a jack, in which freedom of lateral movement is desired.

During the course of development six complete seatings were submitted to exhaustive tests for load bearing capacity, repetitive loading and deflection under load. Measurement of load was made by a proving ring (sensitivity 128 lb per div.) and deflection was measured by taking the average of the readings of three dial gauges, graduated in 0·0005in, symmetrically arranged about the load axis. The relationship between load and deflection was plotted (Fig. 5) and in all

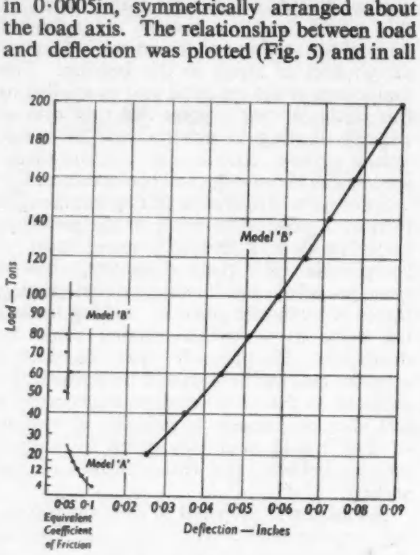


Fig. 5

cases the scatter of results was small enough to be considered within the reading errors of the proving ring dial gauge. The tolerances between which the friction factor can be held is not yet known. At this stage of development it can be said that none of the tests performed indicated that a wide deviation is probable. Moreover, it is thought that the principle of operation, which depends upon the rolling action of a flexible member, will tend toward constancy. From the results of the tests given below, it will be seen that the equivalent coefficient of friction of the hydraulic seating is considerably lower than that of a well-made spherical seating of equal size; as can be seen in Fig. 5. According to A. G. Tarrant a coefficient of friction of the order of 0·5 is to be expected at loads producing stress in the seating exceeding 1000 lb per square inch.

Since the strength of concrete, due to lack of uniformity of structure, can be stated only as an average of a given volume, it is clear that the manner in which the crushing load is applied must influence the indicated load at all stages up to the point of failure. Means of applying the load at a given rate can be implemented with small error and can therefore be repeated on alternative machines. The degree of flatness of the platen surfaces in contact with the specimen can be controlled by normal machining methods.

If it is accepted for the present that a self-aligning platen be used for the standard test of concrete, of the alternatives, ball seating or hydraulic seating, the latter appears to be a more reliable method than the former of achieving free movement under load. The cost of the hydraulic seating is considerably less than that of implementing a suitable design of ball seating. Although a limited number of tests were carried out, examination of figures given below of the comparative tests of the two seatings will give some idea as to the trends to be expected.

It will be observed under " Deflections of Cubes " that the ball seating, after initially aligning to the direction of the load, produces practically the same condition of test as that given by the fixed platen method. This might be a satisfactory method providing a design is specified which will in all conditions behave in a constant manner.

A notable feature of the results is that the failing loads on the concrete cubes average 3 to 6 per cent lower when tested with the hydraulic platen. This is thought to be due to a more uniform distribution of load causing failure to occur when the average stress reaches the strength of the weakest portion of the cube. This being so, this method of test measures the minimum strength of a cube.

It will be observed in the test results that those performed with the hydraulic seating were less consistent than in the case of the normal ball seating. It is not yet known if this is the result of experimental variation or whether unknown effects were occurring, which were not demonstrated by the limited series of tests. It may be due to greater sensitivity brought about by the reduction of friction. The means of proof lie largely in the direction of a sustained programme of tests involving as many individual tests as possible, performed on a variety of testing machines all fitted with a hydraulic seating.

Tests With Self-Aligning Hydraulic Seating

Series 1, using hydraulic seating model " A "

Failing loads of 4in concrete cubes

	Ball seating	Hydraulic seating
Mix proportions by weight 1 : 8·5/0·8:		
Average load (9 cubes), lb	37,000	35,100
Standard deviation, lb	1,600	1,800
Average as per cent	100	95
Deflections of cubes as cast, ratio top/bottom at 30,000 lb	1	1·7
Mix proportions by weight 1 : 6·8/0·5:		
Average load (9 cubes), lb	79,900	75,300
Standard deviation, lb	1,700	2,700
Average as per cent	100	94
Deflections of cubes as cast, ratio top/bottom at 60,000 lb	1	1·9
Mix proportions by weight 1 : 4·8/0·5:		
Average load (9 cubes), lb	60,900	58,900
Standard deviation, lb	2,400	2,100
Average as per cent	100	97
Deflections of cubes as cast, ratio top/bottom at 55,000 lb	1·1	1·6

Series 2, using hydraulic seating model " B "

Failing loads of 4in concrete cubes at 24 days

Mix proportions by weight 1 : 3·8/0·35:		
Average load (12 cubes), lb	187,500	153,000
Standard deviation, lb	6,520	9,860
Average as per cent	100	82
Deflections of cubes as cast, ratio top/bottom at 120,000 lb	1	1·1

Failing loads of 4in concrete cubes at three months

Mix proportions by weight 1: 3·8/0·35:		
Average load (6 cubes), lb	201,300	196,800
Standard deviation, lb	4,330	13,290
Average as per cent	100	98
Deflections of cubes as cast, ratio top/bottom at 170,000 lb	1	1·4

Series 3, using hydraulic seating model " B "

Failing loads of 4in concrete cubes at six weeks

Mix proportions by weight 1 : 6·0/0·55:		
Average load (12 cubes), lb	112,300	108,400
Standard deviation, lb	4,100	4,160
Average as per cent	100	97
Mix proportions by weight 1 : 3·8/0·35:		
Average load (12 cubes), lb	196,400	176,100
Standard deviation, lb	4,320	11,670
Average as per cent	100	90

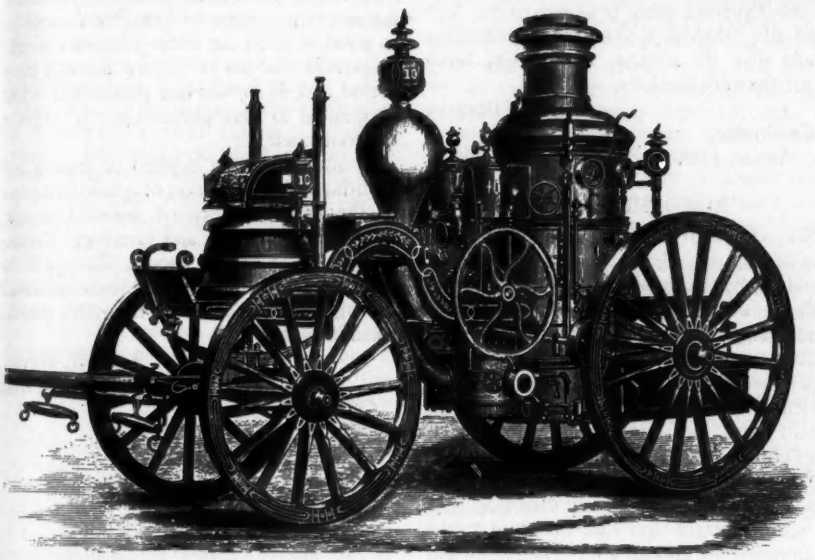
Failing loads of 6in concrete cubes at 28 days

Mix proportions by weight 1 : 3·7/0·35:		
Batch (1):		
Average load (6 cubes), lb	406,000	368,000
Standard deviation, lb	6,730	17,100
Average as per cent	100	91
Batch (2):		
Average load (6 cubes), lb	396,000	376,000
Standard deviation, lb	10,000	8,250
Average as per cent	100	95

The tests were carried out at the Road Research Laboratory of the Department of Scientific and Industrial Research by kind permission of the Director of Road Research, who is, however, in no way responsible for the conclusions drawn above. The British Rubber Producers Research Association, and Clockhouse Engineering, Ltd., assisted in the development of the seating.

ENGRAVINGS OF 1874

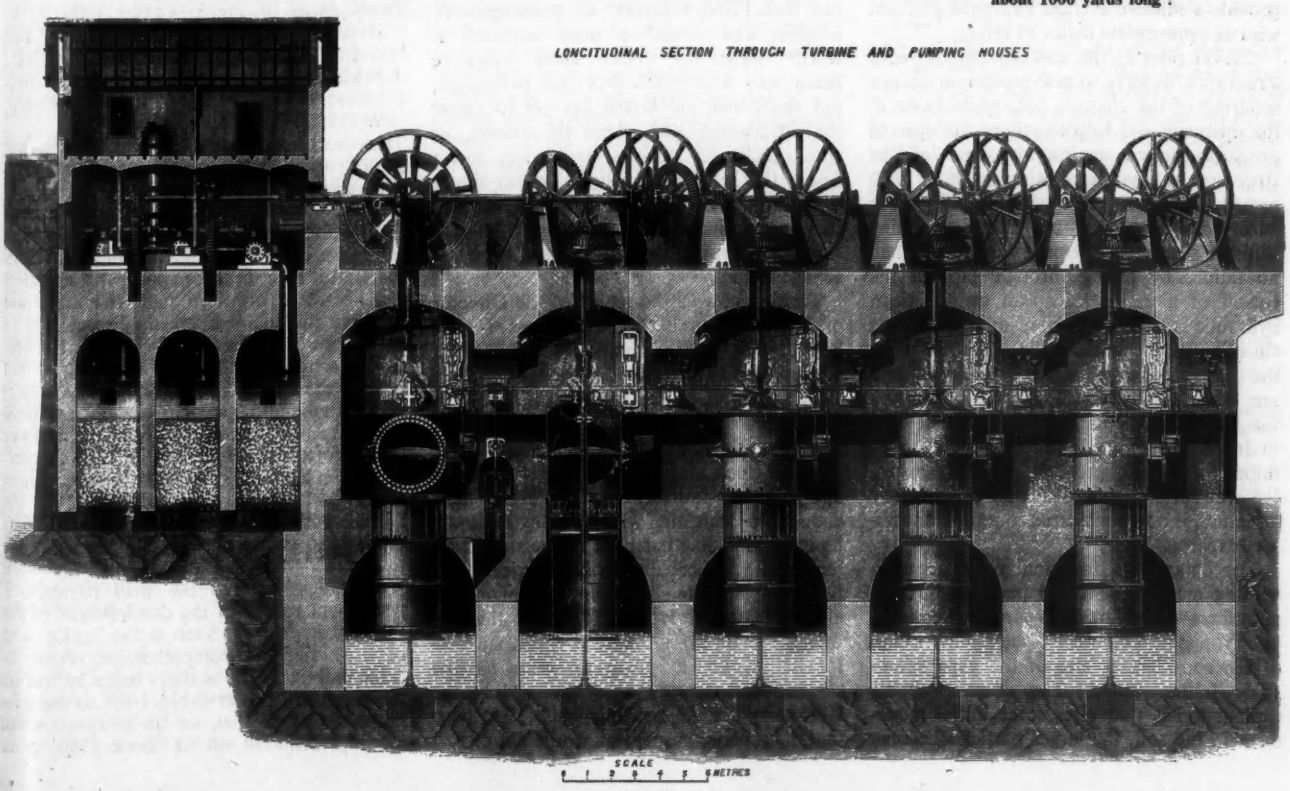
We believe the "rolling bridge" between St. Servan and St. Malo, illustrated in this engraving from our issue of June 12, 1874, survived well into the present century. The bridge ran on rails laid upon the bottom of the estuary of the River Rance at St. Malo. Our article says very little about the method of operation but the "bridge" was presumably pulled back and forth by chains. Surprisingly enough for so short a "passage," the accommodation provided for two classes of passengers, first and second, and horses and carriages could also be carried.



By February 6, 1874, the date on which the engraving alongside appeared in our pages, fire engines made in this country had become more or less "functional" in design. Not so in the States. There they remained ornate. This "double plunger steam fire engine, Class II" was constructed by the Amoskeag Manufacturing Company, Manchester, New Hampshire. A peculiarity of the engine, it seems, compared to those used in this country at the same time, lay in the retention of a flywheel. It was capable of delivering 600 gallons of water per minute.

Notice in the engraving below, from our issue of March 27, 1874, the figure of a man, top left centre, introduced to give scale. The illustration depicts the turbine house at Bellegarde, near the confluence of the Rhone and the Valserine, at that time just entering service. Each turbine was capable of developing some 630 h.p. They were of Jonval construction and were designed and made by Jacob Rieter and Co., of Winterthur, Switzerland, to utilise a maximum fall of 42ft 9in and a minimum of 36ft 2in. What strikes a modern reader as remarkable is the means of transmitting the power. It will be observed from the engraving that each turbine drives a wheel or wheels through bevel gearing at the top of its shaft. From each of these wheels there ran a rope drive, first from the roof of the turbine house in a ravine to another wheel on the lip of the ravine and thence through other stations separated by distances of 426ft to 570ft, to the point of use. One such drive was about 1000 yards long!

LONGITUDINAL SECTION THROUGH TURBINE AND PUMPING HOUSES



LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

CUT-OFFS IN MODERN HYDRAULIC DIVERSION WORKS ON ALLUVIAL RIVERS

SIR,—I have read with interest the first article by Professor S. Leliavsky on cut-offs in hydraulic works, but regret that the basic principles of cut-off design to safeguard against piping were not more clearly expressed. Unless a hydraulic structure retaining a head of water is founded on an impermeable base, there is percolation of the water through the subsoil to the downstream side. This seepage water may emerge under such a pressure that it causes either heave of the soil at the downstream toe of the structure, or piping beneath the structure. According to past records of failures of hydraulic works, heaving, which would occur as soon as the structure were completed and subject to a full head of water, has not been apparent where piping has resulted in an eventual collapse.

Assuming that the cause of piping is erosion of the soil at its contact surface with the structure, creep is defined as the path of a water particle along this surface. The introduction of cut-offs beneath the floor of a hydraulic structure increases the amount of creep and reduces the average hydraulic gradient, thereby giving a safer structure. Furthermore, the vertical creep along the cut-off surface is generally more effective in contributing to the safety of the structure than the horizontal creep, as the sedimentary deposits on which hydraulic works are usually built, are more permeable in the latter direction. The total creep is selected to provide a suitable average hydraulic gradient with an appropriate factor of safety.

Cut-off piles at the downstream end of a structure also serve to give protection against scouring of the channel bed, while those at the upstream end help to reduce the upward pressure exerted against the base of the structure by the percolating water. With regard to the two basic types of piling, it is hardly correct to say that thin sheet piling walls of steel are extremely vulnerable when no failure by piping through gaps in the cut-off of a major European or American hydraulic structure incorporating steel piling cut-offs has been recorded. Rather is it the case that the mechanics of piping failure are better understood to-day and the need for well construction as originally devised in India and Egypt to safeguard the costly flood gates and attendant mechanisms in the event of a failure of part of the hydraulic structure, is now considered to be an unnecessary expense.

The concept of frictional resistance preventing movement of soil particles through gaps in a cut-off wall is surely discounted by Professor Leliavsky's later description of the considerable size of the gaps left in some Indian wells. The more probable explanation is that after some initial movement in the soil, the larger particles become jammed together in the gaps and a build-up of finer particles occurs behind them with the eventual formation of an inverted filter. This phenomenon is obviously what occurred in the experiment using Giza sand, the sand particles becoming packed hard under continual water pressure. The formation of such inverted filters would be encouraged in a steel sheet piling cut-off where the gap in the locks of the piles is small and the particle path somewhat tortuous. Hence, the principal factors in the selection of a steel sheet piling section for a cut-off should be the maximum lock clearance and the principal soil grain size.

Unfortunately, the soil description given in the article is somewhat misleading and not in accordance with present-day practice, as the Egyptian sand is stated to be finer than silt, whereas a standard classification would give the reverse, sand grains being larger than silt particles.

L. BEAZLEY

Cambridge,
August 13th.

ROAD RESEARCH

SIR,—In your leading article last week you suggest that some of the studies of safety problems by the Road Research Board might well be circulated widely. The result, I would suggest, would be to destroy any confidence, at least among engineers, in its recommendations. To take one subject which has been of great interest recently, the Board says, in connection with vehicle inspection :

" Only a compulsory scheme will detect the vehicles which are grossly defective. . . .' It is immediately clear that the word " all " is intended to appear after " detect." But the Board is in favour of a compulsory scheme, and therefore must consider it worth while to detect these defective machines. Yet, in the very next paragraph, one finds that the Board has yet to assess the effectiveness, let alone the results, of spot checks on vehicles in service, and I assert that engineers will be in no doubt that only an examination of a random sample of the vehicles on the road can support the proposal for regular universal vehicle testing.

Turning now to the report of the Director of Road Research, I conclude, as I have before, that the information sought is not always that which would be useful. An example is afforded by the discussion of the " Maxaret " anti-skid device, which features so frequently in pronouncements from this source. Such a device merely prevents one applying any individual wheel brake hard enough to lock any wheel at any instant ; its immense value has been demonstrated on trucks and trailers in North America. But the " simpler system " sought by the Director already exists ; it is to build cars so that the wheels remain firmly on an irregular surface. I wish to see a racing or *gran turismo* car included among the vehicles used by the laboratory for its braking tests ; I believe that the superior suspension would not merely avoid skidding, but allow far higher overall retardations to be achieved.

S. GRIEVESON

Darlington, August 13th.

JAMES NASMYTH, 1808–1890

SIR,—I shall be grateful to any of your readers who may be in a position to help me trace original business correspondence, accounts, &c., that may throw light on the activities of the firm of Nasmyth, Gaskell and Company, or of its successors, Nasmyth, Wilson and Co., Ltd. Research is now being conducted into this pioneer among engineering firms, with a view to publication, and I am anxious to ensure that nothing of importance be overlooked.

It would be helpful if anyone who has documentary evidence of any kind would be so good as to let me know whether it would be possible for me to borrow it for a short period and, if so, whether permission would be granted to have photo-copies of relevant material made ?

In addition, I am hopeful of tracing and ensuring the preservation of items illustrative of the life and work of James Nasmyth, the Scottish engineer and inventor. Correspondence, accounts, papers, &c., will be welcome, and I should be particularly pleased to learn of any models of Nasmyth's patents which may exist.

J. F. W. BRYON,
Borough Librarian

Central Library,
Eccles, Manchester.
August 7th.

Literature

Development of Power Cables. By P. V. HUNTER, C.B.E., Hon. M.I.E.E., Fel. Am.I.E.E., and J. T. HAZELL, M.B.E., A.M.I.E.E. George Newnes, Ltd., Tower House, Southampton Street, London, W.C.2. Price 25s.

THIS short history of the evolution of power cables originated some twenty-three years ago, when one of the authors, Mr. P. V. Hunter, was collecting material for his presidential address to the Institution of Electrical Engineers in 1933. In the preparation of this material it soon became apparent that unless a deliberate effort were made to obtain and preserve the many interesting specimens of early power cables they would be lost to posterity. Accordingly Mr. Hunter and his colleague, Mr. Hazell, resolved to collect and catalogue as much of the available material as they could acquire. One result of their work can be seen in the Hunter-Hazell collection of power cables which forms part of the electrical section of the Science Museum, South Kensington. Of its kind this collection is almost certainly unrivalled. Another outcome of the work was that it inspired the wish to make a permanent record of the development of the cable maker's art. Such is the background of this brief but comprehensive review of cable making. The authors begin by tracing the origins of power cables back to the telegraph cables, so that, for the relatively small loadings required up to about 1880, gutta

percha and vulcanised indiarubber became established as reliable dielectrics for arc lamp conductors. But the growth of load that began with the introduction of the incandescent filament lamp marked the start of the development of power cables of the greatly increased carrying capacity that was required. One of the early substitutes for gutta percha and rubber as a material for insulating electrical conductors was "vulcanised bitumen," which was patented in 1881 by William Callender and formed the basis of the Callender solid system which was developed after the formation of the Callender Bitumen Telegraph and Waterproof Company in 1882. In the meantime a different method of using a bitumen was being developed by Edison, who encased solid copper conductor rods, of segmental section, in an iron pipe, using millboard diaphragms as separators, the tubes then being filled by suction pump with hot compound, which was allowed to cool and solidify. Progress with lead sheathing is traced back to 1879, when François Borel made a small hydraulically-operated lead press which extruded a sheath of semi-molten lead to envelop the insulated conductor.

Impregnated jute was another method of cable insulation that found favour in the 1880s, and a short chapter in the book refers to installations carried out by the Siemens brothers, Berthoud and Borel, Brooks (with his oil-filled jute-insulated system) and, later, by Fowler and Waring. Other chapters devoted to low-voltage conduit systems—rubber insulated cables including "cab-tyre" sheathing—and the Grosvenor Gallery installation of the late 1880s bring the story up to the controversy that had by then grown between the two schools of thought—the exponents of high-voltage a.c. on the one hand, and low-voltage d.c. on the other. The next important stage in cable making, then, was the tubular main developed by Sebastian de Ferranti, who was only twenty-one when he conceived the idea of transmitting power from Deptford at 10,000V—and that at a time when the accepted limit of voltage for distribution was about 3000V. Bearing in mind the voltage used and the fact that Ferranti's patent provided for the paper insulation to be applied helically in strips, we can regard the tubular main as a principal forerunner of the modern high-voltage cable. By the end of the century there were in service several installations of paper-insulated cables at voltages of 11kV.

In the meantime the introduction of polyphase transmission in America in 1893 had created a demand for three-phase cables. At the same time the rapid growth of industrial loads and the consequent call for high transmission voltages exposed the limitations of the solid-insulated cable and provided the necessary incentive for the development of the oil-filled and "oilostatic" systems of insulation and, later, of the various kinds of gas pressure cables. Here (with but a brief glance at the present and future prospects) the authors wisely acknowledge that "in this review of power cable development we have reached a point at which it would seem convenient to call a halt" on the ground that it becomes increasingly difficult to view more recent events with the necessary objectivity. For our part we found objectivity to be one of the endearing attributes of this eminently readable book.

Design of Piping Systems. Second edition. By M. W. KELLOGG COMPANY. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 120s.

THE subject of pipework design has been badly neglected in Great Britain, and there is very little literature published in this country. On the other hand, this matter has been dealt with extensively in the U.S.A. and this latest volume, prepared by the M. W. Kellogg Company, deals in a most comprehensive manner with one section of pipework design, namely, the calculation of stresses set up in piping systems under working conditions and the various factors which contribute thereto.

The first chapters deal with creep in steel pipes at high temperatures and the effect on allowable working stresses. Reference is made to the various components of creep, but the authors lay greater stress on the actual creep rate over a period of time rather than the stress required to produce fracture after a specified life. It is stated that the stress required to produce 1 per cent creep in 100,000 hours is generally less than that required to produce fracture in the same time, but this statement is based on tests ranging up to 10,000 hours. In this country, however, tests have been carried out for much longer periods and, in fact, results have been obtained for creep rupture for periods up to 68,000 hours, and these do not bear out the statement made by the authors. In any case as far as pipework is concerned, the creep rupture is of far greater importance than the creep extension. On page 36 the authors refer to an allowable working stress based on 100 per cent of the creep rupture figures, but it is more common in this country to use a working stress equivalent to two-thirds of the creep rupture.

The subject of local components such as bends and branch pieces has not been overlooked, but in the case of the former a full treatise is not given as a very large amount of work has been done by other investigators, to which reference is made. In Chapter 4 a number of simplified methods of flexibility analyses are given, but it is doubtful whether any of these methods are quicker or easier to operate than that described by E. B. Cocks in a paper published by the Institution of Civil Engineers in 1932. The most important section of the work is that described in Chapter 5 dealing with Flexibility Analysis by the General Analytical Method. This system was originally proposed by the M. W. Kellogg Company in 1941 and offers several advantages over other systems. The Kellogg system can be used for pipe assemblies having any number of anchor or restraining points. It is purely mathematical and avoids the necessity of preparing restraining moment diagrams. It is thus eminently suitable for use in a computer, and it has been adopted by several organisations as their standard method for designing piping systems when a computer is available. Without this mechanical aid the mathematical method is lengthy and great care must be taken to ensure that no calculation errors occur.

The model test described in Chapter 6 is of great value as a check in the case of a particularly complicated and important piping system, but due to economic considerations it can hardly be used as a routine method. There is a section dealing with expansion pieces and also pipe supports. These chapters describe the effects of these items on the flexibility and stressing of pipes, and whilst they do not break fresh ground the book would not be complete without them. The last section refers to vibration in pipes. This is a subject about which very little information has previously been published and the cause and prevention of noise in steam pipes is still somewhat obscure. Steam pipe designers will therefore welcome the help given by this chapter of the book.

Generally the book is the most important work dealing with piping design which has been published for many years, and the Kellogg Company is to be congratulated in preparing this treatise and making it available to the engineering profession.

Creep and Fracture of Metals at High Temperatures. Proceedings of a Symposium held at the National Physical Laboratory. H.M. Stationery Office, York House, Kingsway, London, W.C.2. Price 30s.

THIS substantial volume contains the text of, and the discussions upon, twenty-two papers presented at the symposium, which was attended by physicists, engineers and metallurgists from about fifteen countries. The contents reflect the advances that have been made in the study of plastic deformation and fracture at high temperatures in the period that has elapsed since the previous conference on creep, initiated by the N.P.L. in 1946. The papers are grouped into four sections: deformation processes in simple materials, creep resistance of complex materials, theory of fracture, and work on tertiary creep and fracture. In the discussion of theories of the processes taking place in metals at high temperatures practical problems were not lost sight of, and thus the record contains many data of practical value in connection with the behaviour of several high-temperature resisting materials developed during recent years. Theoretical studies have tended to explain rather than to predict the behaviour of these materials, but the work described on grain boundary conditions, ageing effects, the part played by fine precipitates of an additional phase, and other structural features dealt with in the papers have made possible a qualitative forecast of the probable behaviour of a material in creep. The report of the symposium will be of interest to all concerned with the development of creep-resisting materials for use at high temperatures.

Differential Equations. By S. V. FAGG, B.Sc., A.R.C.S., D.I.C. The English Universities Press, Ltd., 102, Newgate Street, London, E.C.1. Price 7s. 6d.

ONE of the small books of an "Applied Mathematics Series," this is intended to give the student a sight of the varied problems to which differential equations are applied. It calls for no more than sixth form mathematical training, the ability to differentiate and to integrate standard functions. The study is taken far enough to introduce the Laplace transform, and examples are worked using this method on single and simultaneous linear equations. Numerous exercises are provided, the answers being presented after the text. The index refers not only to the text, but also to the subjects of the examples.

Books Received

Electrical Principles. By H. Cotton. Cleaver-Hume Press, Ltd., 31, Wright's Lane, Kensington, London, W.8. Price 12s. 6d.

A.C. Switchgear. Vol. I, *A Survey of Requirements.* By J. R. Mortlock. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 50s.

British Iron and Steel Federation, Statistical Year Book for 1954—Overseas Countries. British Iron and Steel Federation, Steel House, Tothill Street, Westminster, London, S.W.1. Price 15s.

The Ultimate-Load Theory Applied to the Design of Reinforced and Prestressed Concrete Frames. By A. L. L. Baker. Concrete Publications, Ltd., 14, Dartmouth Street, London, S.W.1. Price 18s.

Peaceful Uses of Atomic Energy. Vol. I, *The World's Requirements for Energy: The Role of Nuclear Power.* Sales and Circulation Section, Department of Public Information, United Nations, New York, U.S.A. Price 57s.

Producer Gas Trials

THE Ministry of Fuel and Power, together with the Fuel Research Station and the Ministry of Transport and Civil Aviation, recently published the results of a series of tests on producer gas as a fuel for road vehicles. The work, which concentrated on compression ignition engines, was intended both to complete the development that took place in this country during the wartime shortage of petroleum fuel and to point the way to the use of indigenous fuels in those parts of the Commonwealth where vegetable products or low-grade solid fuels are abundant and oil must be imported. The fuel used in these trials was anthracite for the most part, but on one occasion charcoal was tried and proved a satisfactory alternative.

The producer gas plant was mounted on a two-wheeled trailer and was basically the same as the plants used in the second world war. However, most of the tests were carried out with generators in which the air from the tuyere passed across the active part of the fire bed and then upward into a cone in the upper part of the fuel hopper. The final gas filter consisted of a cylindrical slag-wool screen.

Spark Ignition Engines

Two petrol-engined vehicles were converted to run on gas by fitting special gas mixing chambers, providing means to cut off the petrol supply to the carburetter, and advancing the ignition timing about 10 deg. The first was a 1947 Vauxhall "J" model, with a six-cylinder engine of R.A.C. rating 14. Since the trailer weighed 11 cwt charged, the performance of the combination was so poor that testing was abandoned after 1500 miles; in the opinion of the Ministry, a four-cylinder engine might have been more adaptable to the new fuel.

The second vehicle was a 5-ton Bedford lorry with a six-cylinder engine of R.A.C. rating 27. The trailer for this vehicle was always a cross-draught type, and weighed about 17 cwt. During the initial stages of testing a cylinder head gasket was blown, and four more were used in the total of nearly 30,000 miles' running. A straight mineral oil was used in the crankcase, and the engine deteriorated rapidly in service: big-end bearings, pistons and rings were all renewed at about 10,000 and 15,000 miles, and the main bearings, the valve guides and the exhaust valves at the latter figure. Cylinder bore wear was at the rate of 1722 miles per 0·001in, although over a quarter of the running was on petrol. Fuel costs, however, including the cost of filter cartridges and excluding servicing of the trailer, were slightly reduced, at least for loads averaging about 4 tons. The vehicle was regarded by its drivers as unsatisfactory. Both these vehicles, it appears, were handicapped by the wide spacing of the gear ratios.

Compression Ignition Engines

The diesel engines used for the trials were 7·7-litre A.E.C. units with C.A.V. mechanical governor fuel pumps. The fuel system was modified by C. A. Vandervell and Co., Ltd., to provide only sufficient fuel to initiate combustion; since the characteristic of the pump was to increase fuel delivery per revolution as the speed rose, at least at low rack settings, a fixed setting was not acceptable for best oil economy. A retractable stop was therefore provided, and the governor modified to reduce the rack setting 1mm between fuel pump speeds of 560 and 640 r.p.m.; the characteristic with the retractable stop engaged therefore rose slightly below and above the speeds named and dropped between those speeds. The retractable stop could be withdrawn by a control on the instrument panel to permit immediate reversion to full oil delivery. In practice, oil fuel consumption was 45 to 50 per cent of that with no gas burning. Injection commenced about 32 deg. b.t.d.c.

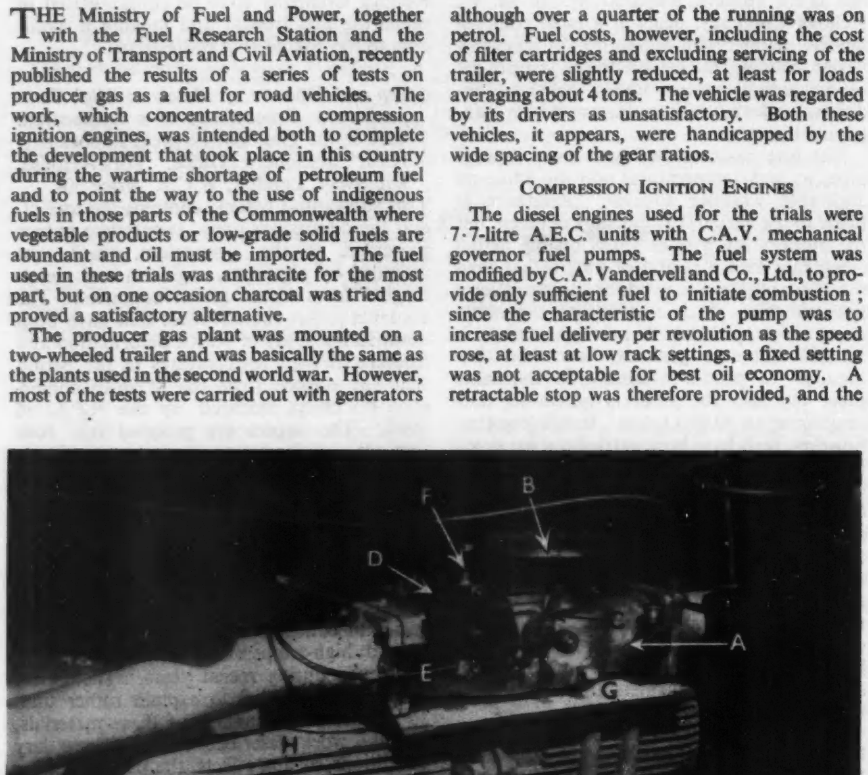
The gas was mixed with air in the device illustrated. The air was drawn in by the ejector effect of the gas stream, and a fine adjustment for the spring-loaded flap valve was provided to allow the driver to compensate for fluctuations in the quality of the gas, and to economise on anthracite when taking little power from the engine. "Popping back" in the manifold was experienced, and a relief valve was fitted to the cover plate to safeguard the induction system. The unit was originally assembled of light alloy castings, but during development phosphor-bronze bearings for the throttle butterfly spindle and a steel air valve flap were adopted.

Two vehicles were again used, a "Mammoth Minor" 10-ton truck and a fifty-six-seat double-deck bus. Both towed trailers charging 500 lb of anthracite, sufficient for about 200 miles' running. The lorry ran fully loaded, and was rather less costly on dual-fuel than normal diesel operation. It was generally a satisfactory performer, but consumed four sets of cylinder head gaskets in 22,000 miles; cylinder bore wear was high, at 1330 miles per 0·001in, although detergent oil was used.

The bus was tested both on long runs and simulated services in congested and hilly country. The fuel cost was higher than for a normal vehicle, particularly on the slower service. After about 18,000 miles, the engine was found to be in good order, except that the flame rings in the head gaskets were cracked and the metal around them corroded. Bore wear was 7063 miles per 0·001in; the marked difference between the rates of wear in two similar engines is attributed to the fact that even one faulty filter—and filter life averaged 1600 miles on the bus and 1100 on the truck—could pass enough solid matter to severely accentuate wear.

Conclusions

The reports of the Ministries consider the possibility of reducing the demand for imported fuel in this country, and conclude that conversion of compression ignition engines to producer gas is practicable, although only at a sacrifice of operating efficiency. Petrol engines, unless amply powerful for their work, would be unsatisfactory, and the fuel saving relatively small. It is clear that the performance of these plants in service is highly susceptible to variations in driving technique and maintenance methods.



A.—Gas throttle valve.
B.—Air entry to mixing chamber.
C.—Air flap-valve.
D.—Adjustment for spring-rate of flap-valve.
E.—Driver's Bowden cable control of gas-air mixture strength.
F.—Explosion release valve.
G.—Asbestos-lined platform for mixing chamber.
H.—Exhaust manifold.
I.—Fuel pump.

Gas-air mixing valve installed on A.E.C. 7·7 litre diesel

Metal-Rectifier Welding Set

A NEW metal rectifier welding set—MCR 375—has been introduced by Quasi-Arc, Ltd., Bilston, Staffordshire. It consists of a transformer, regulator and selenium plate metal rectifier, has class "A" insulation, is specially designed for single operator welding duty, and is constructed to B.S. 171 : 1936 and B.S. 638 : 1954 where applicable.

Any electrodes from 16 S.W.G. to ¼in diameter can be used with the equipment, which runs from a three-phase, 50 c/s supply, having an input voltage range of 360-440V. The maximum welding current is 375A at 35 arc volts at a duty cycle of 50 per cent. The maximum continuous current is 250A d.c. and the open circuit voltage is 64V. Rectification is by a three-phase bridge connected selenium metal plate rectifier, giving a stable arc with a power factor of about 0·8 at maximum output and balanced mains loading.

The step-down transformer is double-wound and an inbuilt three-phase contactor is connected in the supply to the primary winding. Stepless control of the output over the whole range between 30-375A is made possible by a three-phase moving core reactor, which is connected between the transformer secondary winding and the rectifier. The core travels in adjustable guides through two mechanically coupled lead screws, giving silent operation. The reactor is operated by the rotary control handle mounted in the top cover of the housing and linked with a rotating calibrated drum which is visible through an unbreakable transparent window.

An h.f. filter circuit can be fitted when the equipment is intended for use with an h.f. unit.

Cooling is by a fan incorporating a centrifugal switch which prevents the equipment being used if the fan is not working. The direction of rotation is unaffected by the phase relationship of the input connections and the air flow is directed downwards to lessen the internal accumulation of dust.

The equipment is mounted in an angle-iron frame with a detachable sheet steel casing in the form of two wrap-round pressings and a louvred top cover. The control panel is recessed and thus protected from damage or accidental operation. Start and stop buttons are fitted and an indicator lamp shows when the equipment is energised. A d.c. ammeter and a voltmeter can be fitted if required. The plugs for the welding cables are clearly marked with the polarity and are fully shrouded but accessible. The input terminals can be reached by removing a small panel in the side of the housing. The set is provided with a centrally mounted lifting eye and the whole equipment is supported on floor skids. It weighs 8 cwt 1 qr and measures 32in by 25in by 46in. A manually-towed and steerable four-wheeled undergear is available.

Marine Radar Equipment

AT a Press showing last week we were able to see the Type 14 marine radar equipment made by Kelvin Hughes (Marine), Ltd., 99, Fenchurch Street, London, E.C.3. The equipment will be put on the market on September 1st. It is designed particularly for craft where considerations of size and weight, as well as of expense, have hitherto precluded the installation of radar. At the same time, the performance of the new unit is stated to be better than that required by present Ministry of Transport specifications. Built to cover a range up to 48 miles, the set is stated to have a minimum range of 35 yards or less, a range discrimination of better than 35 yards, a range accuracy of 1 per cent of indicated range, a bearing accuracy of 1 deg., and a bearing discrimination of 1·3 deg.

The equipment comprises the aerial system (scanner unit) shown in Fig. 1, the transmitter, display unit (Fig. 2), power unit and junction box, and a motor-generator set. The total weight is 310 lb, of which the scanner unit accounts for 90 lb, and the display unit 40 lb.

Operating at 9320–9500 Mc/s, the transmitter is provided with a 60kW magnetron, working with a recurrence frequency of 1100 pulses per second. Two pulse lengths, 0·1 and 0·3 microsecond, are used to provide optimum picture quality both on long and short ranges, the pulse length being automatically selected by the range switch. Using saturable core transformers has made it possible to dispense with thermionic valves in the modulator, thereby achieving greater simplicity and reliability. Tuning of the local oscillator is facilitated by a neon lamp. The radio frequency head is equipped with a broad band T.R. cell. The transmitter measures 16in by 15in by 9in and is arranged for bulkhead or deckhead mounting.

Of compact design, but with a full range of controls, the display unit is fitted in gimbals for mounting on the deckhead, bulkhead or a pedestal, the angle being adjustable to suit the viewer. As plan-position indicator it has a 9in cathode-ray tube with preset electrostatic focusing, which requires no subsequent adjustment. In order to obtain the best results under conditions of clutter from sea, rain or snow, a differentiating (F.T.C.) control as well as a swept gain (S.T.C.) control is provided. For range measurements a variable range marker and also calibration rings are available. The local oscillator tuning indicator, the range marker dial, and the indication of range in use are all visible inside the viewing hood. All controls are arranged around the hood, and each has an illuminated identification panel. Five range scales are provided, these being ½–3 miles (continuously adjustable) 6, 12, 24 and 48 miles. Separate monitoring of the transmitter and receiver is provided.

The power unit and junction box houses all power supplies other than the valve heater transformers, which are located in each individual unit. The start-stop switch, standby switch and aerial control switch are also mounted on this unit.

Designed for direct-on-line starting, the motor generator requires no special starter and therefore its dimensions are kept small. Output voltage is automatically controlled for a wide range of input voltage by means of a magnetic amplifier regulator. D.C. or a.c. mains of all standard voltages can be used for operating the set.

In the construction of the scanner aerial unit a slotted wave guide radiator has been used, which is stated to be a new development in British marine radar. This makes it possible to dispense with the conventional reflector, thus reducing wind resistance and weight, while at the same time the electrical characteristics are greatly improved. In fact, it is stated that side lobes are suppressed to the point where no side lobe echoes are obtained. The construction of the slotted radiator was, however, a difficult production problem.

As may be seen from the detail shown in Fig. 3, the angle of the slots varies along the radiator. By means of a suitable choice of angles the power radiated from each slot can be varied in such a way that side lobes are reduced to as small a value as possible. At the same time the circumference of all the slots must be kept the same, so that the depth must vary as a function of the angle. The distance between slots is kept to within ±0·002in, while the angle must be accurate to within five minutes of arc. Although the wave guide tends to deform owing to the release of stresses during machining, it must be kept straight. By various means it was found possible to improve the performance of this aerial and to obtain a beam which is even narrower than theory would lead one to expect. It is stated that the horizontal beam angle is 1·3 deg. to half-power points. The vertical angle is 20 deg. to half-power points. The scanner rotates at 20 r.p.m.

Uniformly high performance is more readily obtained and quantity production facilitated by the use of printed circuits. These are obtained by spraying a "Bakelite" base with a 0·0025in layer of copper, and after printing on it the required wiring layout in acid-resisting ink, etching away the surplus metal. Components can be connected to the copper by soldering, both electrically and/or mechanically. After all connections have been made the copper is protected against corrosion by means of a lacquer. Another step taken to ensure that performance should not alter was to make use of "potted" components wherever possible. As an example, the calibrator used for range finding is moulded into a solid block of resin and is thereby protected from climatic conditions and mechanical damage.

The equipment, the first prototype of which was installed a year ago, is stated to have been operated for several thousand hours, including sea trials lasting two to three months.

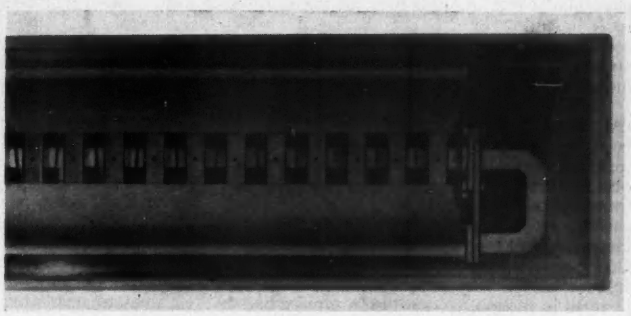


Fig. 3—Portion of slotted waveguide radiator of the scanner unit

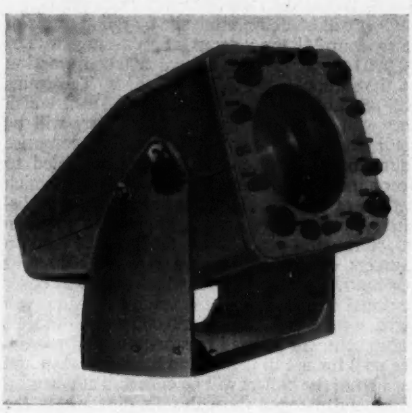


Fig. 2—Display unit complete with mounting bracket suitable for deckhead, bulkhead or deck pedestal use

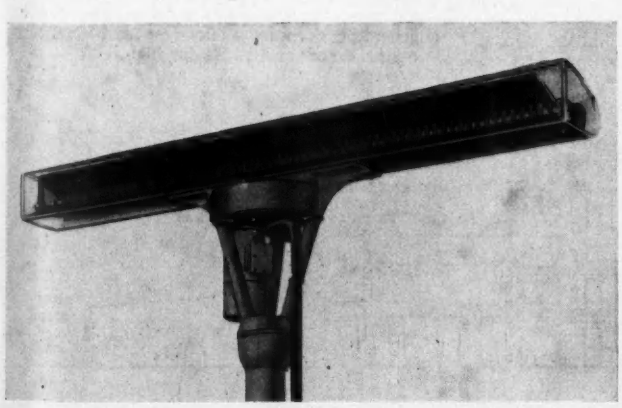


Fig. 1—6ft long scanner unit with end-fed slotted waveguide radiator

Boundary Lubrication

A LUBRICANT of extreme film strength has been evolved by United Lubricants, Ltd., United House, Cromwell Place, S.W.7. This material is the result of a discovery, rather than progress along the established theories of surface-active agents, and the present hypothesis of its action is that it is highly penetrative and forms an enduring deposit in the fine irregularities of a metal surface. There is, moreover, no tendency for this film to become the base of any further deposits, so that there is no risk of lubrication by this means being overdone.

The effectiveness of this technique was demonstrated to us on the American Timken testing machine, running a bearing outer race against a parallel roller. A variety of lubricants were tested and it was shown that seizure took place under loads of the order of 100 lb for engine oil, 120 lb for soluble oil, and 170 lb for sulphurised cutting oil: water as a lubricant carried 110 lb without seizure. The addition of about 10 per cent of "Dextrol" 905 (which was seen to emulsify immediately in the water) allowed most of these lubricants to remain effective under the highest loads applicable, roughly 700 lb. Interestingly enough, seizure could be induced with the additive-bearing oils: a detergent multi-grade engine oil rose from 110 lb to cause seizure to 500–550 lb. The sulphurised cutting oil, at first, seized under 280 lb, but at every subsequent attempt the failing load was higher: this is explained by the fact that the surface-active agent in the cutting oil was inhibiting the action of the additive, and as the original agent was destroyed by overheating the additive came into its own. As an extreme test for the additive, sulphuric acid was mixed with the water emulsion lubricant, without any apparent adverse effect.

A striking feature of the demonstration was that, with the conventional lubricants, the roller was abraded to a depth of about $\frac{1}{16}$in in each test. With the additive in use, it was not possible under similar or aggravated conditions to do more than polish the surface of a small spot. It was also shown that, once the additive had been in action, the lubricant feed could be

discontinued for at least a short interval without seizure occurring.

The additive freezes at −28 deg. Cent. and boils at 270 deg. Cent. It is non-inflammable and serves to raise the flash point of any oil to which it is added, so that such applications as mining machinery are envisaged. Its cost is such that it is expected that low-grade oils supplemented with the concentrate will oust high-grade oils from many applications. The extreme film strength engendered in any oil is regarded as valuable in an internal combustion engine, particularly when running in : for this purpose, it is included in " Carburol Super," which conveys also oxidation resistance, dispersant and anti-acid properties, and improved viscosity index to engine oils.

" Oiliness " is, of course, put to a most severe test by cutting tools, and " Dextrol " 905 has been applied with success to various metal forming operations. Advantages that have been observed have been that the effort needed, both to make the cut and to drive the slides, has been usefully reduced, that speeds and feeds can be increased, and that tool lives tend to improve. One interesting instance was the broaching of a splined bore ; on occasions the broach had jammed in the job, so that the workpiece had to be cut away in order to salvage the tool. Seizure was heralded by a howling noise and a great increase in driving force, and it was therefore practicable to provide the operator with a can of concentrate to apply when these symptoms appeared. The additive immediately reduced the load on the tool from around 1200 lb to 450 lb, and, of course, prevented a stoppage of the machine.

High Marnham Power Station

We learn from the Central Electricity Authority that work has now started on the High Marnham power station, situated on the River Trent. It will have an ultimate capacity of 1000MW ; with five 200MW machines it will represent the largest single station and possess the largest sets installed in this country, and the first set is due for commissioning in 1959. The boilers and turbines, designed on the unit principle, will operate on a steam cycle of 2350 lb per square inch at 1050 deg. Fah., reheating to 1000 deg. Fah. The cross-sectional arrangement of the station is illustrated here, the longitudinal axis being east to west.

The tandem compound turbo-generators,* arranged longitudinally in the turbine house, will have three low-pressure and three high-pressure feed heaters capable of producing a final feed temperature of 460 deg. Fah., the third-stage low-pressure heater being arranged as a high-level deaerator. The feed water will be returned to the boilers by two-stage pumping, there being two 100 per cent booster and two 100 per cent main feed pumps, one pump providing automatic standby on the other. The generators will be hydrogen-cooled at a pressure of 30 lb per square inch. There will be two gantry cranes in the turbine house, one designed to handle the heaviest lift of 168 tons and the other of lighter duty to carry out general maintenance.

The boilers having a drum height of 130ft are designed in two casings, one containing the superheat and the other the reheat furnace. They will be pulverised-fuel-fired, the coal being stored in overhead bunkers having a capacity of 2270 tons per boiler. Each boiler will be equipped with six mills, five of which will maintain maximum continuous rating, and the fuel will be fed into the furnaces through forty-eight burners arranged for corner firing. Each boiler will be fitted with a mechanical grit arrester and an electrostatic precipitator, and the flue gases from the five units will be discharged to atmosphere through two reinforced concrete chimneys at a height of 450ft.

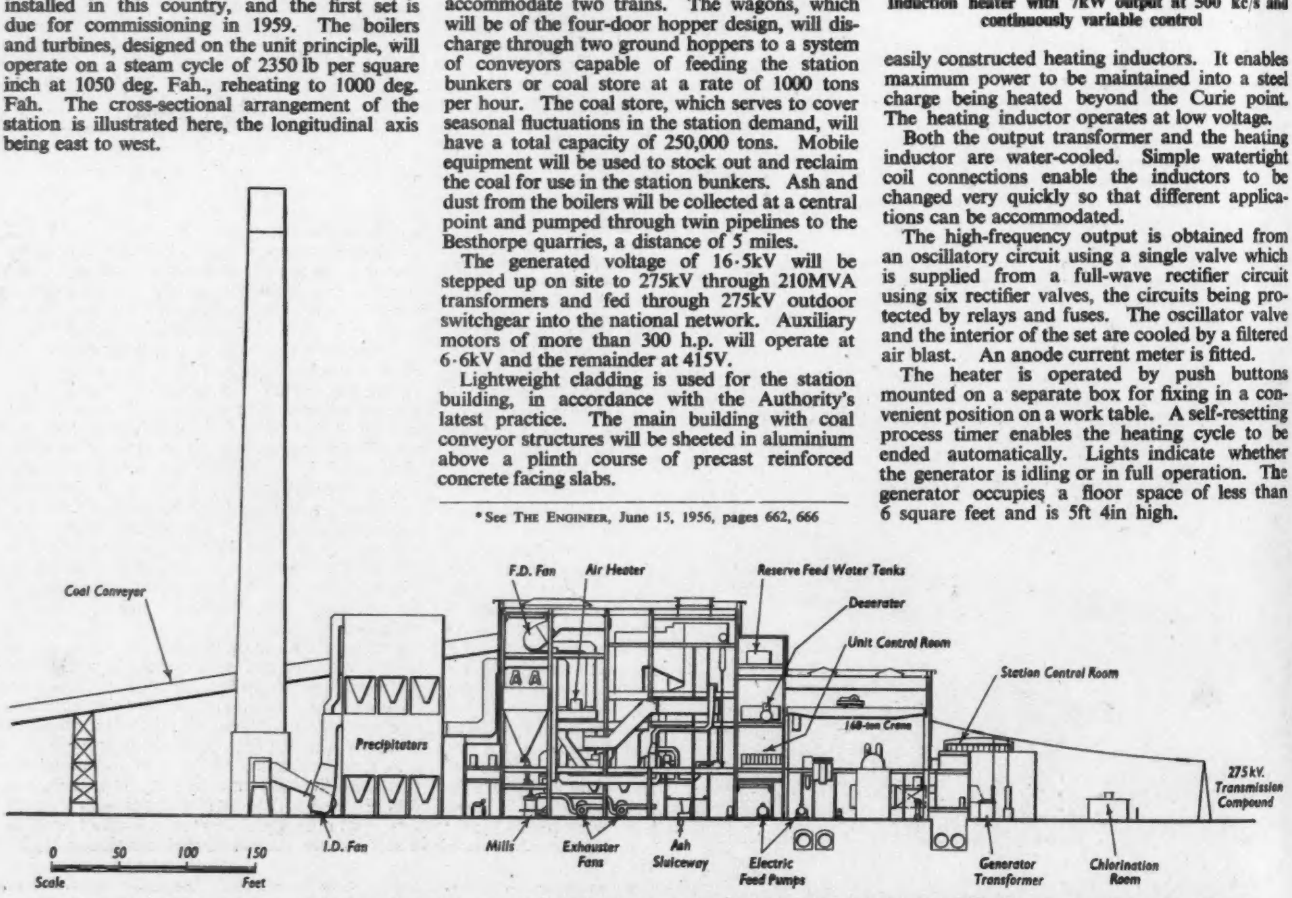
Cooling water for the condensers will be circulated through a closed system of five cooling towers by five circulating water pumps. Each tower will have a capacity of 5,400,000 gallons per hour and will be connected into the system to be available on any machine. Fresh water will be drawn from the river at the rate of 33,000,000 gallons per day and, less evaporation, will be returned to the river continuously.

Coal will be delivered to site by rail in trains of thirty-four 24½-ton wagons, at an average rate of 10,000 tons per day, the annual coal consumption of the station being 2,500,000 tons. The trains will be shunted into exchange sidings, from which they will be drawn and to which they will be returned after emptying. These sidings comprise fourteen tracks, each 1765ft long, designed to accommodate two trains. The wagons, which will be of the four-door hopper design, will discharge through two ground hoppers to a system of conveyors capable of feeding the station bunkers or coal store at a rate of 1000 tons per hour. The coal store, which serves to cover seasonal fluctuations in the station demand, will have a total capacity of 250,000 tons. Mobile equipment will be used to stock out and reclaim the coal for use in the station bunkers. Ash and dust from the boilers will be collected at a central point and pumped through twin pipelines to the Besthorpe quarries, a distance of 5 miles.

The generated voltage of 16·5kV will be stepped up on site to 275kV through 210MVA transformers and fed through 275kV outdoor switchgear into the national network. Auxiliary motors of more than 300 h.p. will operate at 6·6kV and the remainder at 415V.

Lightweight cladding is used for the station building, in accordance with the Authority's latest practice. The main building with coal conveyor structures will be sheeted in aluminium above a plinth course of precast reinforced concrete facing slabs.

* See The Engineer, June 15, 1956, pages 662, 666

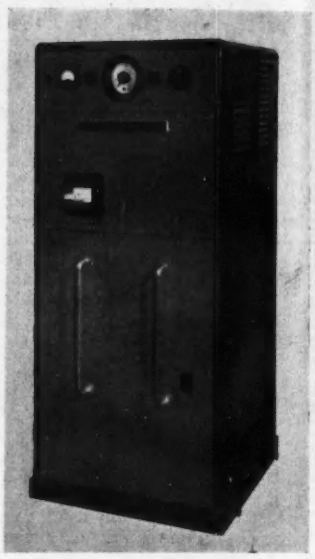


Cross section of High Marnham power station which will have five 200MW hydrogen-cooled sets, the steam conditions being 2350 lb per square inch at 1050 deg. Fah. with reheat to 1000 deg. Fah.

7kW Induction Heater

The photograph reproduced here shows the general appearance of an induction heater with an output of 7kW at 500 kc/s which has been developed by The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. This equipment is designed to be equally suitable for use in repetition work or as a general-purpose tool for processing batches of different articles.

Variable control of output power is produced by the heating inductor being fed from an output transformer whose secondary can be moved smoothly over the primary by a lever projecting from the front of the cabinet. The control allows optimum conditions to be set up for a wide range of applications and permits the use of



Induction heater with 7kW output at 500 kc/s and continuously variable control

easily constructed heating inductors. It enables maximum power to be maintained into a steel charge being heated beyond the Curie point. The heating inductor operates at low voltage.

Both the output transformer and the heating inductor are water-cooled. Simple watertight coil connections enable the inductors to be changed very quickly so that different applications can be accommodated.

The high-frequency output is obtained from an oscillatory circuit using a single valve which is supplied from a full-wave rectifier circuit using six rectifier valves, the circuits being protected by relays and fuses. The oscillator valve and the interior of the set are cooled by a filtered air blast. An anode current meter is fitted.

The heater is operated by push buttons mounted on a separate box for fixing in a convenient position on a work table. A self-resetting process timer enables the heating cycle to be ended automatically. Lights indicate whether the generator is idling or in full operation. The generator occupies a floor space of less than 6 square feet and is 5ft 4in high.

Sound System for Colston Hall Organ Tuning

BECAUSE the organ at the Colston Hall, Bristol, is very sensitive to even slight variations of temperature and humidity in the organ chamber, the instrument has to be tuned whenever it is to be used. The size of the task of tuning can be estimated from the fact that the new organ, which took five years to build, has 5372 pipes; fourteen wind chests, mostly in halves of the slider type; eighteen wind chests of the unit type; and seventeen reservoirs. There are nearly 4000 electromagnets in the organ and the coils carry a total length of 300 miles of copper wire. An insulated multi-core cable carries 800 wires from the console to the various mechanisms operating the organ, which was built by Harrison and Harrison, Ltd., of Durham.

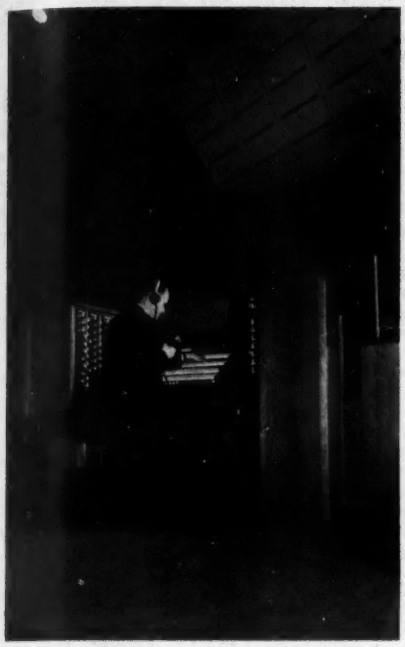


Fig. 1—The tuner of the organ in Colston Hall, Bristol, communicates with the organist by microphone and headphones. The organ chamber is behind the grill, top right

The all-electric console is detached from the organ itself so that the organist at the console (Fig. 1) can be in the view of the audience and the conductor, and is well placed to hear the instrument in correct balance. This arrangement makes tuning difficult, in that the tuner is some distance from the console. Moreover, the "principal" (the stop from which all the others are tuned) is also some distance from the other parts of the organ. Furthermore, the volume of sound from the pipes would be overwhelming to the tuner working nearby.

To overcome the tuner's difficulties, The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2, has devised a system of two-way communication between the tuner and the player. Two moving-coil microphones are installed near the "principal" stop, the note from which is transmitted to the tuner through a moving-coil headphone with padded earpieces (Fig. 2). The tuner is also equipped with a microphone specially designed for cancelling extraneous noise, so that he can communicate with the organist.

The system makes use of a modified 8–10W G.E.C. amplifier, which is mounted on a shelf at the base of the organ chamber.

This amplifier has been designed for three fader-connected inputs, "Microphone," "Music 1" and "Music 2." It has a bass attenuator control connected in series with the microphone stage, to enable maximum clarity of speech and music reproduction to be obtained under various acoustic conditions. The microphone sensitivity is such that at high volume a low output microphone of the ribbon type will fully load the amplifier—an important point when an extraneous-noise-cancelling microphone is being used in addition to moving coil microphones. The amplifier works under constant-working or instant-operation conditions. Terminals situated at the rear of the chassis enable the h.t. supply to the valves to be independently switched, either by means of a local switch or, for distant control, by means of a suitable relay.

The moving coil microphones installed have "Concert" heads and an output impedance of 15–30 ohms. They have very level frequency response with a well-maintained bass response, making them very suitable for relaying music. In addition to the four moving coil microphones, the extraneous-noise-cancelling microphone and the moving coil headphone, three moving iron headphones have been supplied. These headphones have a total weight of only 8 oz each and can be worn for long periods without fatigue.

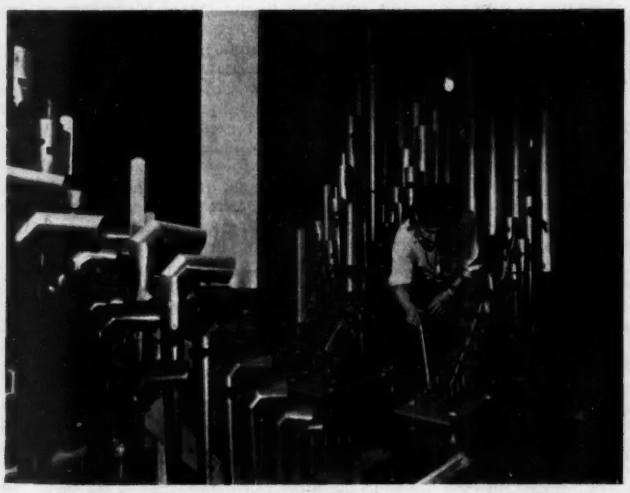


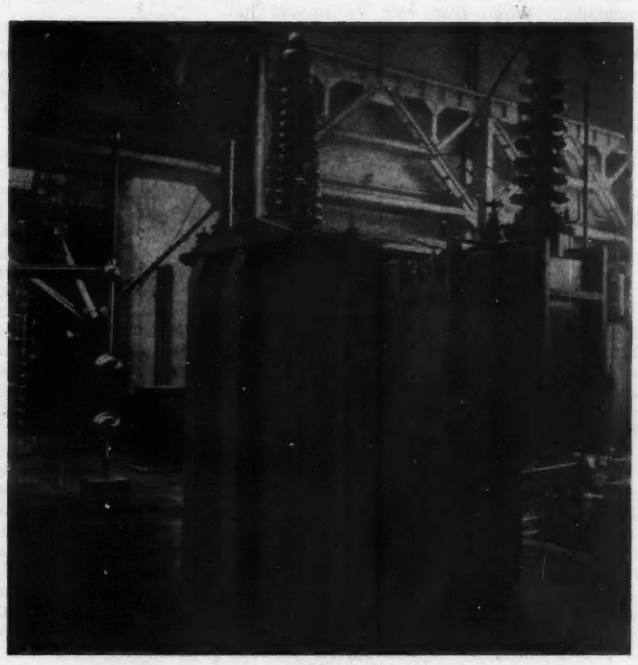
Fig. 2—Through moving coil headphones the tuner receives the note picked up by two microphones placed near the "principal" stop. He can speak to the organist through the extraneous-noise-cancelling microphone on his headset

Impulse Tests on 275kV Super-Grid Transformer

IMPULSE tests on a full-scale prototype of one phase of a three-phase 120MVA, 275/132kV auto-transformer were recently carried out at the maker's works, Bruce Peebles and Co., Ltd., Edinburgh. Four such transformers, all with on-load tap-changing gear on the 132kV side, are being made by this company for the Clyde's Mill substation of the South of Scotland Electricity Board.

The testing arrangements are shown in the illustration below. The prototype transformer is seen in the foreground and behind it the sphere gap and the 1875kV impulse generator. In accordance with British Standards, the type tests comprised the application of full-wave impulses at 525kV, 790kV and 1050kV, followed first, by two chopped-wave impulses at 1210kV, and then by two further full-wave shots at 1050kV; the wave shape throughout was the standard 1×50 microsecond.

It was decided that, having withstood these tests successfully, the prototype transformer should be subjected to a series of successively higher voltage tests possibly until eventual breakdown, and the maker states that the 275kV winding was subjected to more than seventy impulses ranging uniformly from 1050kV full wave up to 1660kV chopped wave without breakdown or any signs of serious weakness. These tests indicated that the design of the transformers provided adequate safety margin for any conditions they are likely to meet in service on the 275kV super-grid, and that the mechanically-strong arrangement of disc type high-voltage winding used on the prototype will be suitable for use on transformers for systems operating at 330kV and 380kV.



Prototype single phase of a 120MVA, 275/132kV, three-phase auto-transformer for Clyde's Mill substation undergoing impulse tests at the maker's works in Edinburgh

---

NON-MAGNETIC COMPRESSOR.—An unusual Service requirement for a 350 lb per square inch air compressor of low magnetic content has been met by the Hymatic Engineering Company, Ltd., Redditch, Worcs. The compressor itself is a variant of an aircraft unit for higher pressures, and provides two stages of compression with a stepped piston. Both cylinder and intercooler are cooled by air impelled by the spokes of the driving pulley. The crankcase is made of "Tungum": the compressor is required to stand high "*g*" loads—this is common on naval equipment as a precaution against damage by mines—and therefore enlarged main and big end bearings are used. A ½ h.p., 220V d.c. motor drives the compressor, and can be manually controlled or set for automatic starting at 320 lb per square inch and stopping at 350 lb per square inch. The air receiver is formed of "Tungum" tube and to give some protection to the plant it takes the form of two equal circles with the motor and compressor side-by-side in between them. The large surface area associated with a 1 cubic foot receiver of this form allows a high proportion of inhaled moisture to be expelled from the two drain taps. There is also an oil and water trap in the final delivery line. The free air delivery is 0·5 cubic foot per minute and the weight of the plant 260 lb.

Industrial and Labour Notes

Iron and Steel

British steel production during July averaged 326,400 tons a week, and was therefore at an annual production rate of 16,971,000 tons, compared with a rate of 16,002,000 tons in July last year. Production last month would undoubtedly have been higher had it not have been for the ban on overtime imposed by maintenance workers, a ban which has now been withdrawn. Pig iron output averaged 240,400 tons a week in July, compared with 230,800 tons in July last year.

The Iron and Steel Board has stated that the total quantity of steel available in the first six months of this year was 11,000,300 ingot tons, which was 5·1 per cent more than in the comparable period of last year. During the first half of this year producers added 14,000 tons to their stocks and exports amounted to 1,720,000 tons. The supplies to the home market were thus 9,170,000 tons, an increase of 4·7 per cent when compared with the first half of 1955. Imports of finished steel by consumers in the first half of this year, however, have been estimated at 656,926 tons, against 347,340 tons in the comparable period of last year. The Iron and Steel Board says that imports of the heavier products, such as plates and sections, were well above the 1955 levels, whilst imports of sheet and tinplate were lower. But a considerable part of the additional steel supplies in the first six months of this year has been added to consumers' stocks.

In some recent comments on the continuing expansion of this country's steel making capacity, the British Iron and Steel Federation has suggested that, even with a high rate of scrap recovery, pig iron requirements over the next few years will increase more rapidly than steel production. Part of the reason for this, the Federation says, is that steel production will increase faster than the supply of scrap arising at home. A significant proportion of that supply results from the scrapping of plant and equipment made twenty years or more ago. Steel consumption was then rising less rapidly than steel production is now. The Federation goes on to say that more home-produced pig iron will be required to reduce the industry's dependence on overseas supplies of pig iron and scrap. In the last few years imports of pig iron and scrap have amounted to more than 1,000,000 tons annually. While that rate of import has obviously involved the expenditure of much less foreign exchange than would have the corresponding import of finished steel, the Federation observes that it is not clear for how long reliance can be placed on the availability of such tonnages. World steel output is rising rapidly and, while it is not out of the question that new sources of pig iron for export may develop overseas, there will clearly be a tendency for the tonnage of scrap entering world trade to fall from its recent high levels.

Settlement of B.M.C. Dispute

At the end of last week it was announced that a settlement had been reached in the dispute between the British Motor Corporation and the unions representing its employees. The dispute arose over the method of dismissal of redundant workers, and resulted in a strike—which was not fully supported—in the Corporation's factories. The strike began on July 23rd.

During last week both sides conferred with the chief industrial commissioner of the Ministry of Labour, and subsequently held a joint meeting. The settlement was the outcome of these negotiations. It was agreed that compensation should be paid to workers dismissed by the Corporation at the rate of one week's pay for every worker with three or more years' continuous service, and two weeks' pay for those with ten years' service or more. It was also agreed that local representatives of the unions should examine with the British Motor Corporation the possibility of finding vacancies in which some of the displaced workers could be absorbed, and that there should be " appropriate consultation " between the Corporation and the unions in any future cases of redundancy. In the light of this settlement, work was resumed in the Corporation's factories last Monday.

Overseas Trade

The Board of Trade has given a provisional figure of £266,300,000 as the value of the United Kingdom's exports in July. This, it says, was about the same as the monthly average for the first half of this year, and 10 per cent above last year's average monthly rate. The period covered by the July figures this year contained twenty-five working days. Imports in July were valued at £320,300,000, which was 3 per cent below the monthly average for the first half of the year, and 1 per cent under the average for 1955. Re-exports in July were valued at £9,800,000. The excess of imports over exports and re-exports was therefore £44,300,000 in July ; this was £6,500,000 less than the average for the first six months of this year.

Information about the volume of the United Kingdom's overseas trade in the second quarter of this year shows that the index of volume of exports (1954=100) was 116·9, compared with 111·8 in the first quarter. Thus, in the first half of this year the volume of exports was nearly 10 per cent above the figure recorded for the corresponding period of 1955. The Board of Trade has drawn attention to the fact, however, that the recorded figures for the first half of last year were somewhat distorted by the effects of dock strikes in the latter part of 1954, while the figures for the second half of last year were affected by the strike in the May-July, 1955, period. If these influences are taken into account, the Board of Trade suggests that the volume of exports in the first six months of this year was about 6 per cent higher than in the comparable period of 1955. The volume index of imports in the second quarter of this year, at 113, was about the same as in the first quarter. For the first half of this year the import volume as recorded was approximately 3·5 per cent higher than in the corresponding period of 1955, but, the Board of Trades observes, here again the comparison is influenced by the strikes and the actual increase was probably about 2 per cent.

Prices

Some useful information about movements in the prices of materials used in manufacturing industry is given in the current issue of the *Board of Trade Journal*. There, it is stated that, although the prices of fuels as well as of some individual industrial materials rose significantly in the first half of this year, there was on average a slight reduction in the prices of basic materials between December, 1955, and June, 1956. During that period the fall in the prices of rubber and of several non-ferrous metals, including copper, was the most significant, and was a factor which helped to keep down the prices of materials used in the engineering industries at a time when higher prices for iron and steel had to be faced. But the Board of Trade shows that, in contrast with the general trend of prices for basic materials, producers' prices for manufactured goods continued to rise steadily between December, 1955, and June, 1956. This reflected to a considerable extent the continued rise in wage rates, as it was a period in which the index of weekly wage rates rose by 6·5 per cent, five times as great as the increase in the preceding six months.

The index for materials used in the mechanical engineering industries (June 30, 1949=100) remained relatively stable during the first six months of this year, the June figure of 176·3 being only 0·1 per cent above that for last December. Increases in the prices of the miscellaneous iron and steel items included in the index (up approximately 6 per cent on average) and engineering castings (up 9·3 per cent) were almost counterbalanced by decreases in the prices of various copper and brass items, the price of brass ingots, for example, falling by 25·3 per cent. On the other hand, the index for materials used in the electrical machinery industry, after rising in the first quarter of this year, declined thereafter until in June, at 184·2, it was 5·9 per cent below the December, 1955, figure. The principal cause of this drop was lower prices for copper and brass items, which, carrying a much larger weight in this index than in the mechanical engineering materials index, heavily offset the increased iron and steel prices.

Employment and Unemployment

The Ministry of Labour's latest report on the employment situation in Great Britain says that at the end of June there were 23,031,000 people (15,258,000 men and 7,773,000 women) in civilian occupations. This was about 15,000 more than a month earlier.

During June, the number employed in the manufacturing industries declined by 15,000, but this decrease was offset by increases, largely seasonal in character, in the basic industries, in building and contracting, the distributive trades, and professional, financial and miscellaneous services. An analysis of employment in the manufacturing industries in June shows that in the engineering, metal goods and precision instruments group there were 2,791,000 at work, or 2000 less than in May. The June total, however, was 31,000 higher than that recorded a year earlier. Employment in the vehicle building industry declined during June by 9000 to a total of 1,237,000, which was 6000 more than in June last year. The report notes that in the four weeks ended June 27th the employment exchanges in Great Britain filled 156,000 vacancies, a decrease of 6000 compared with the preceding month. The number of vacancies notified to the exchanges but unfilled on June 27th was 407,000. This was 10,000 more than on May 30th, but 54,000 less than a year previously.

About unemployment, the Ministry reports that on July 16th there were 238,137 people registered as out of work, compared with 222,577 on June 11th. The increase in unemployment between the two dates is said to have been due to an increase in the number (45,437) described as temporarily stopped. The Ministry estimates that the number of people registered as out of work on July 16th represented 1·1 per cent of the total number of employees, compared with 1 per cent on June 11th.

Confederation of Shipbuilding and Engineering Unions

As we go to press the debates on the resolutions submitted to the annual conference of the Confederation of Shipbuilding and Engineering Unions are in progress. Altogether, thirty-nine resolutions have been put forward by various unions within the Confederation. The first eleven of them relate directly to wages, and urge the Confederation's executive to proceed with a claim for wage increases. There are five resolutions calling for a reduction in working hours ; one of them, from the Amalgamated Engineering Union, asks the executive council to " pursue strenuously negotiations for a forty-hour week without loss of earnings." The resolution adds that " this is now a paramount necessity in view of the introduction of automation in the engineering industry."

The conference, which began on Tuesday, is being held at Hastings. At the opening session the president of the Confederation, Mr. H. G. Brotherton, delivered an address in which he criticised the Engineering and Allied Employers National Federation for " taking the unprecedented step of rejecting a wage claim before it had been presented." Mr. Brotherton referred also to the subject of redundancy in the engineering and allied industries, urging that every reasonable step should be taken to minimise the difficulties created for the workers.

CERN European Proton Synchrotron

The first annual report of the European Organisation for Nuclear Research, otherwise known as CERN (Conseil Européen pour la Recherche Nucléaire), has been published in Geneva. This organisation came into being in September, 1954, its main aim being to enable European countries to collaborate in fundamental nuclear research of a non-military character. The report covers the first fifteen months in the life of CERN, and is largely concerned with progress in the design and construction of two accelerators for research on high energy particles—a 600MeV synchro-cyclotron which is due to be in operation next year and a 25GeV proton synchrotron which is planned for completion in 1960. Progress on the proton synchrotron as recorded in the report is described here.

THE European Organisation for Nuclear Research, CERN, was set up in September 1954, to provide facilities for European countries to collaborate in fundamental nuclear research work outside the military sphere. A list of member states and of the percentage contribution which they make towards the finances of the organisation, is tabulated here :

Members of European Organisation for Nuclear Research

Member	Contribution up to end of 1956, per cent
Belgium	4·88
Denmark	2·48
France	23·84
German Federal Republic	17·70
Greece	0·97
Italy	10·20
Netherlands	3·68
Norway	1·79
Sweden	4·98
Switzerland	3·71
United Kingdom	23·84
Yugoslavia	1·93

The basic programme of CERN is to organise and sponsor co-operation between its members in the fields of nuclear physics and cosmic rays. Collaboration between national research institutions is being encouraged and CERN is also committed to the task of building and operating an international laboratory. The main installations in this laboratory will consist of two accelerators for research on high energy particles. One of these accelerators is a 600MeV synchro-cyclotron, the design of which was finalised in 1955 with a view to the completion of the equipment in 1957. The second particle accelerator is a 25 GeV proton synchrotron which is scheduled for completion in 1960. Some details of the proton synchrotron abstracted from the CERN report are given below.

Proton Synchrotron

Preliminary plans for the building of a 25 GeV alternating-gradient proton synchrotron were submitted in October 1953, to the European Council for Nuclear Research, an interim organisation which had been set up to pave the way for CERN. Since then detailed design studies of the machine have been continued.

Before considering the progress that has been made with this particular progress it should perhaps be recalled that a proton synchrotron is essentially a machine for accelerating positively charged particles by causing them to describe a circular path in such a way that during each circuit the particles receive one or more high-frequency energy impulses. The particles are thus accelerated with each circuit of the circular path until they attain the required energy level when they may be constrained to strike a suitable target. The constraint which causes the particles to describe a circular path is exercised by a magnetic field which must be made to increase in strength so that, as the energy of the particles increases, the field strength rises correspondingly to keep the orbit of the particles circular.

The principle of operation was outlined in an article on page 271 of The Engineer, February 20, 1953, describing the proton synchrotron at Birmingham University. One important difference is that, in the CERN equipment, which will be more powerful, the magnet is not a continuous ring but is divided into a large number of sections separated by r.f. accelerating cavities and focusing lenses (Fig. 1). Accordingly, in the CERN proton synchrotron the particles receive a series of accelerating impulses in each circuit instead of only one, as in the Birmingham University installation.

The main parameters of the CERN proton synchrotron were decided in December 1954, and since then no major modifications have been made.

In the circumferential path (part of which is shown in Fig. 1), described by the particles there are 50 magnet periods and 100 magnet units. A scale model of a typical magnet unit is shown in Fig. 3. Each magnet unit consists of a focusing sector and a defocusing sector (the field index n being 282 and the operating mode μ being $\pi/4$). Each magnet unit is 4·4m long and the free field gap between the magnet units is 1·6m long. There are ten longer free field gaps (3·0m long) spaced equally around the circumference. Ten pairs of linear correcting lenses and ten pairs of non-linear correcting lenses are also spaced equally around the circumference.

Near the instant of injection of the particles into the circuit the maximum beam cross section is calculated to be 6cm high by 10cm wide assuming certain tolerances in the construction of the machine. All the magnet units have to be

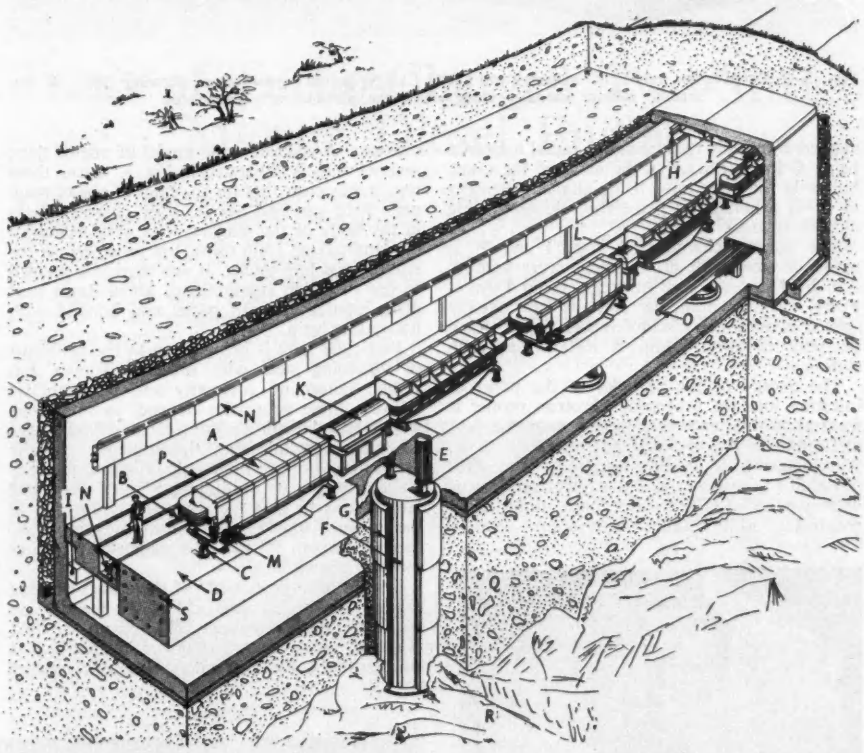


Fig. 1—Perspective of part of ring, foundation, magnet units and r.f. cavities of CERN proton synchrotron

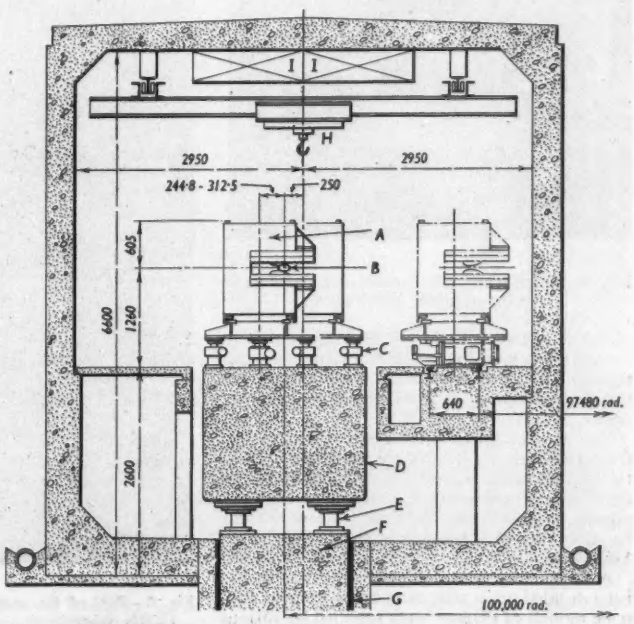


Fig. 2—Cross section of proton synchrotron ring

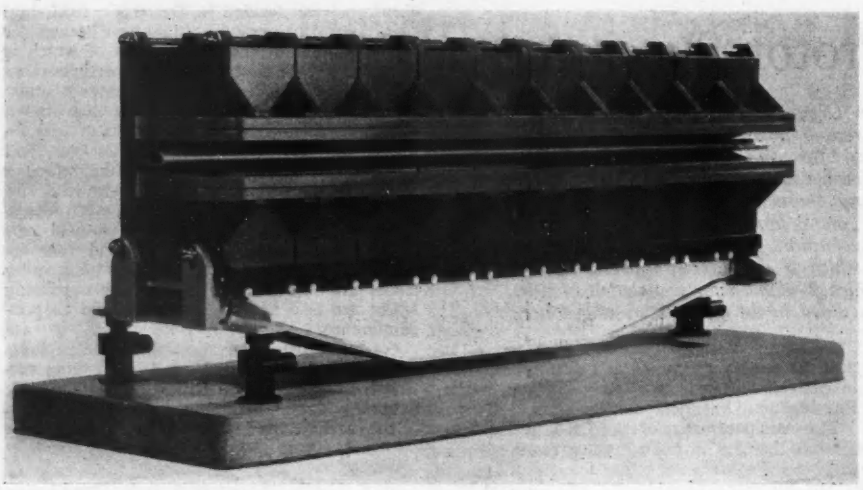


Fig. 3—Reduced-scale model of magnet unit for CERN proton synchrotron showing part of the annular vacuum chamber along which the particles are accelerated

aligned accurately to a circle the radial tolerance being 0·6mm (r.m.s.) at the ends of the units. Similarly the units have to be aligned vertically to lie in a horizontal plane the tolerance being 0·3mm (r.m.s.).

The vacuum chamber (*B*, Figs. 1 and 2), is made of steel with an elliptical cross section, 8cm by 15cm, the wall thickness being 1·4mm. Forty vacuum pumping stations are equally spaced around the circumference, and a 10cm diameter diffusion pump is installed at each station.

The energy of the particles at the point of injection into the proton synchrotron proper is fixed at 50MeV and the injection magnetic field at 140 gauss. An Alvarez-type linear accelerator, 30m long, is to be used for injection. It requires 5MW of r.f. power to feed this linear accelerator with a pulse of 200 microseconds' duration at the instant of injection, which occurs once in

Fig. 4—Proton synchrotron magnet unit placed on its side for magnetic measurements

every five-second cycle of operations. It is necessary to give the particles 50KeV gain per turn and the design provides that 100keV per turn is available. The peak power required per cavity is 3kW.

The magnetic field is increased in one second from 140 gauss, its value at the point of injection, to the maximum field of 12,000 gauss, and this cycle is repeated every five seconds. A peak power of 28MW is required to energise the magnet and the mean power dissipation is 1·5MW.

A satisfactory construction for the magnet has been decided upon after tests carried out on full-scale models of magnet units supplied by various makers. A reduced scale model of one of these magnet units is illustrated in Fig. 3. From these tests it was clear that for the rates of rise of magnetic field specified above, eddy current effects in the body of the magnet yoke were negligible for laminations 1mm thick, but were serious for laminations 1cm thick. It was therefore decided to use precision stampings of about 1mm steel plate interleaved with paper and bonded with hot-setting resin.

Particular care is being given to the problems of obtaining steel with precisely known and stable values of coercivity and permeability. Because these properties depend on impurities which are difficult to control industrially, the designers conclude that the solution to these problems will have to include provision for controlled mixing ("randomising") of the steel laminations to give the necessary uniformity in the magnet blocks. A typical magnet block turned through 90 deg. for magnetic measurements is shown in Fig. 4.

Studies have been made of the effects of eddy currents on the fringing field of the magnet, on the form of the remanent field and on the field inside a model vacuum chamber, from which it appears that a chamber with a wall thickness of 1·5mm can just be tolerated. No serious problems are anticipated in the parallel excitation of the coils, and first experiments with pole-face windings for the correction of magnetic field errors are encouraging. A machine has been designed in which the 1000 magnet blocks will be measured.

A test coil with twenty turns of aluminium has been wound and used to determine the influence of eddy currents in the conductor on the magnetic field in the magnet gap. Another coil

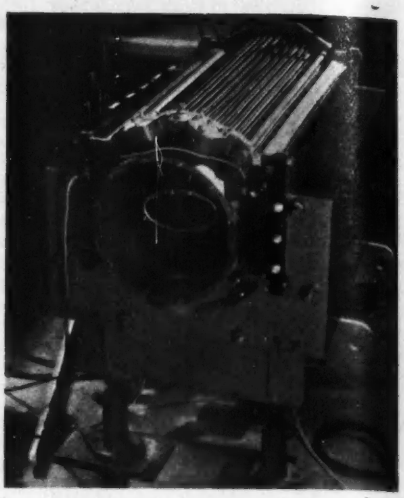


Fig. 5—An r.f. accelerating cavity of the proton synchrotron ring

will be used to study the influence of thermal expansion and to decide the permissible temperature rise of the cooling water in the magnet coils.

One of the r.f. accelerating cavities in the proton synchrotron ring is shown in Fig. 5. The ferrite core of the cavity is saturated by an external magnet and is cooled by water flowing in pipes soldered to a copper sheet, which, in turn, is glued to the ferrite core. A broad-band power amplifier built for use with it has a band width from 0·2Mc/s to 11Mc/s between the 3db points. There are seven stages of amplification; the input signal is 1V, r.m.s., and the power output level is about 4kW. Work done on the servo properties of the automatic tuning system

Fig. 6—Part of the proton synchrotron ring can be seen in the central background of this view of the CERN laboratories. In the foreground is the r.c. structure for carrying the exit beam equipment

suggests that, by using two servo loops, one slow and one fast, sufficiently rapid tuning action can be achieved.

The linear accelerator (" Linac "), which is to form the injector for the proton synchrotron, is being made by Metropolitan-Vickers Electrical Company, Ltd. It is generally similar to the linear accelerator which this company is building for the U.K. Atomic Research Establishment at Harwell, as described in our issue of November 18, 1955, page 733.

Briefly the equipment consists of three resonant cavities, 20ft, 40ft and 40ft long, respectively. The protons are first accelerated to 500KeV by a cascade generator and then accelerated to 10MeV in the first cavity of the " Linac." Acceleration from 10 to 30MeV and from 30 to 50MeV is effected in the next two cavities. Power is to be provided by triode amplifiers driven at a controlled frequency by a 600W c.w. transmitter. Grid focusing will be used in the first cavity. In the remaining two cavities magnetic alternating gradient focusing will be used, with the object of extracting a higher beam current. This method of focusing employs a quadripolar lens inside each drift tube, the lenses being so arranged that focusing in one plane and defocusing in a plane at right angles to the first are interchanged on alternate drift tubes. It is planned to make a new set of drift tubes containing pulsed quadripole magnets for the first cavity and to change over to them before the proton synchrotron comes into operation.

Fig. 7—Ring-shaped channel under construction for the proton synchrotron

The leading requirements of the power supply have been fixed. The main equipments are a motor-alternator set with a flywheel for energy storage and a mercury-arc rectifier with a peak rating of 34,000kW. Parallel connection of the two halves of the magnet coils is assumed and the peak current drawn from the rectifier is 5000A every three seconds or 6400A every five seconds, the d.c. voltage being 5·3kV. Twenty-four single-anode valves are required, arranged in a cascade circuit consisting of two double-three-phase groups with interphase reactors or, alternatively, of two three-phase bridge circuits.

The main requirement in the design of the foundations of the magnet system is that the structure as a whole should be insensitive to temperature changes and ground movements. The diameter of the magnet ring is 200m and the load to be carried is made up mainly of the magnet iron (3200 tons) and the coils (220 tons for copper, 110 tons for aluminium).

The general arrangement of the foundations and of the proton synchrotron ring is illustrated in Figs. 1 and 2. Eighty cylindrical concrete pillars *F*, each about 2m in diameter, are embedded in the rock *R* on a pitch circle diameter of 200m. The magnet units *A*, the r.f. accelerating cavities *K*, and the lenses *L* are supported by a heavy r.c. ring *D* of 2m square cross-section, resting on the pillars. Between the ring and each pillar there are two elastic supports *E*, which allow for relative movement radially between the ring and the pillars, but provide the required constraint against vertical movements.

The proposed method of bringing the magnet units into the ring is illustrated in Fig. 2. Each magnet unit (as indicated by the dotted lines) is brought on electrically driven bogies running on a circular track, to a point opposite the required installation position in the ring. It is then transferred to its permanent mounting and aligned by means of a hydraulic system and screw jacks *C*. The method has been tested with satisfactory results, using a full-scale model magnet unit loaded with 40 tons of lead.

Measurements are being made on the trial ring section of the structure (Figs. 6 and 7) to enable ground movements at different levels to be studied. About a dozen " Invar " wires are fixed in the rock and to the base of the pillars *F* with recording instruments for recording relative changes of level to an accuracy of about 2 microns. Periodical surveys with bubble levels correlate the records of all the instruments and give movements to an accuracy of about 0·1mm.

Studies are being made of a proposed method of checking the position of the magnets after they have been set up and when the proton synchrotron is working. The method involves an automatic survey, using the relative displacements of a photo-cell and an incident beam of light. By this means it is proposed to measure the variations of radius along the eight radial tunnels which will intersect the ring, and thus to measure relative movements of the magnets and the ring. In this way the general configuration of the ring could readily be checked from the control room.

Trials of Turbo-Charged Two-Stroke Marine Diesel Engine

THE marine diesel engine, model " 9RSAD76," which last month underwent its acceptance trials at the works of the makers, Gebr. Sulzer A.G., Winterthur, is a development of the " RS76 " design, to which belonged the engine described in our issue of November 12, 1954, page 663. It is a single-acting, two-stroke cycle, cross-head machine, the principal data being as shown in the Table. By contrast with the earlier engine, which had a reciprocating scavenge blower operated from the crosshead, the present model is equipped with exhaust turbine-driven blowers, and is stated to be the first turbo-charged two-stroke, with cross-scavenge, which has been built at Winterthur.

Extra scavenging pumps or blowers are not necessary, since both starting and manœuvring are readily performed without them, and with a

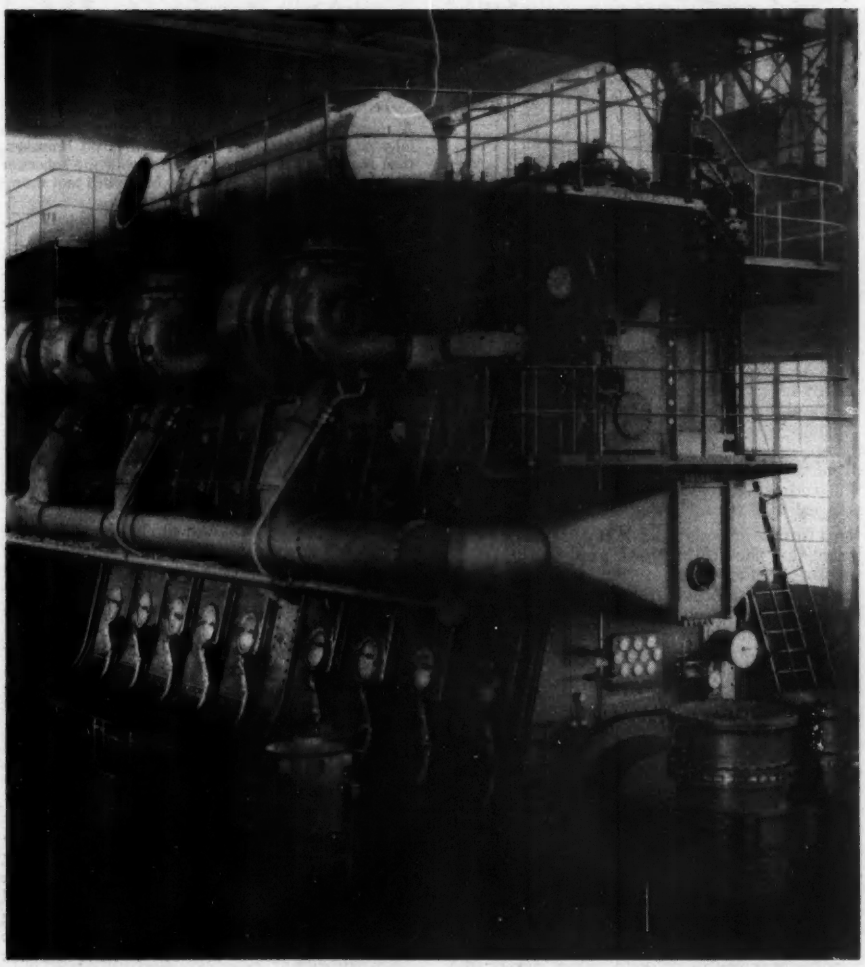


Fig. 1—Nine cylinder, turbo-charged, two-stroke marine diesel engine on test bed. One exhaust driven turbo blower is provided for each group of three cylinders

clear exhaust. The space in the crankcase, which was previously occupied by the reciprocating blower now serves as a wind chest. Our illustration, Fig. 1, shows the arrangement of the turbo-chargers on the engine. Each group of three cylinders is provided with one turbo-charger, the gases from the turbines going into the exhaust manifold, visible at the top of the engine, while the compressed air is collected in the manifold seen below the blowers, which conducts it through two air coolers to the wind chest at the port side of the engine. From there the air goes through non-return valves to the air receiver which is situated above the wind chest.

Marine Diesel Engine Model "9RSAD76"

Number of cylinders	9
Cylinder bore	760mm
Piston stroke	1550mm
Rated output at 119 r.p.m.	11,700 b.h.p.
Maximum output	13,500 b.h.p.
Weight per b.h.p. (approx.)	40 kg

The reason no separate scavenge blowers are required is that use is made of the compression which occurs underneath the pistons for obtaining the scavenge air. During the downward stroke each piston compresses the air in the space underneath and delivers it to the air receiver through non-return valves, so that when the scavenge ports are uncovered early during the subsequent up-stroke, scavenging and partial charging can at once take place. This occurs even at low load or during starting, although under those conditions the turbo-blowers give insufficient pressure. It is claimed

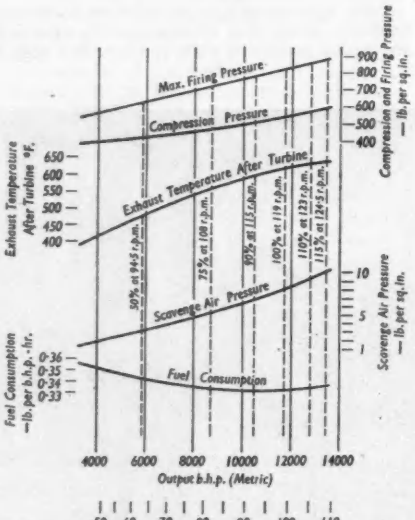

Max. Firing Pressure
Compression Pressure
Exhaust Temperature After Turbine
Scavenge Air Pressure
Fuel Consumption
Exhaust Temperature After Turbine °F.
Compression and Firing Pressure — lb. per sq. in.
Scavenge Air Pressure — lb. per sq. in.
Fuel Consumption — lb. per b.h.p.-hr.
50% at 94·5 r.p.m.
75% at 108 r.p.m.
90% at 115 r.p.m.
100% at 119 r.p.m.
110% at 127 r.p.m.
115% at 129·5 r.p.m.
Output b.h.p. (Metric)
Mean Effective Pressure — lb. per sq. in.

Fig. 2—Performance curves of turbo-charged two-stroke marine diesel engine

as a further important advantage of this arrangement that should the blowers cut out, the pump action of the lower portion of the working cylinders is sufficient to give the vessel 70 per cent of its full speed.

Already, in the non-supercharged "RSD76" version, the piston rod passed through a stuffing-box which had been incorporated in view of the utilisation of heavy fuel oil. The present design is also equipped with a stuffing-box and can burn heavy fuel in the same way.

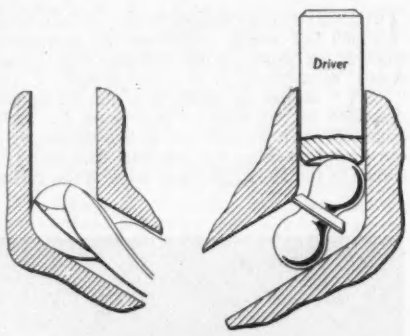
Special attention, it is stated, has been paid to make all the engine parts easily accessible. For this reason, the turbo-blowers are arranged below the upper gallery so as not to restrict the access to the cylinder covers. Special places have been provided on the engine for any parts which may have to be dismantled, so that the engine room itself can be kept clear.

The model "RT67" exhaust gas turbo-blowers are the maker's own design. The shaft carrying the single-stage turbine and the single-stage radial compressor runs in two plain bearings situated at its ends, with a double side thrust bearing at the compressor end, taking the axial forces. Oil from the main engine supply is used to lubricate and cool these bearings. Since the lubricating pumps are separately driven by means of electric motors, no difficulty arises in maintaining full lubrication of the blowers after the engine has been stopped and while the blowers run down. The turbo-blowers are laid out for exhaust temperatures of 260–300 deg. Cent., and speeds of up to 6000 r.p.m. Robust blading has been fitted to the turbine, with large through areas, in order to preclude as well as may be the possibility of damage from portions of a piston ring, if such a ring should break.

Performance curves are shown in Fig. 2. Optimum fuel consumption to date is claimed to be 0·335 lb per brake horsepower-hour, contributing a thermal efficiency of 41 per cent.

Angled Holes with Rounded Corners

In its *Technical Informations*, the European Productivity Centre, Paris, publishes details of designs and methods which either are not generally known, or have been developed by individual firms for a specific purpose, but are thought to have a wider application. One method which has recently been described in



A rounded bend may be obtained by drilling to the intersection of the centre lines of the two branches, then removing the remaining metal with the spherical reamer shown on the left, and the ball-ended tool shown on the right

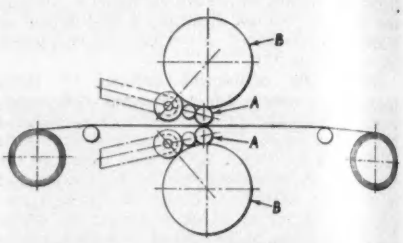
Technical Informations is a way of obtaining angled drill holes in castings, such as are frequently required for conducting fluids. These holes are usually produced by drilling from each end. If an ordinary drill is used, a sharp corner is formed.

A rounded corner, which from the hydraulic point of view is better, can be obtained in the following manner. The hole is drilled with a standard pointed drill from both ends, in such a way that the drill point does not enter further than the intersection of the two centre lines of the bore. The metal left standing on the outside of the bend is then removed with a spherically tipped reamer, as shown in the left-hand portion of the accompanying illustration. In order to round the inside of the bend, a reaming tool with a circular cutting edge arranged coaxially with two spherical ends, is driven through the bore. A tool of this kind is illustrated on the right. To avoid excessively heavy cuts, a number of such tools may be required, beginning with one in which the distance between the ball ends is very short, and continuing with tools of increasing length.

Multi-Roll Cold Rolling Mill

The accompanying illustration gives a diagrammatic view of a design of cold rolling mill which has been introduced by Schloemann Aktiengesellschaft, of Düsseldorf. It is found that a widely varying rolling programme, covering a considerable range of strip thickness, can be carried out only if the diameter of the work rolls can be adapted to the strip thickness, and the present design makes this possible. Moreover, the mills can be used with a separate set of chocks as two-high mills for roughing or finish-rolling.

When using the multi-roll chock set, the back-up rolls are driven and the work rolls rotate by friction. The arrangement enables the diameter of the work rolls to be reduced to less than



Diagrammatic view of multi-roll rolling mill. The work rolls *A* are set off-centre in relation to the back-up rolls *B*, which drive them through friction

half the normal value, a fact which is of particular importance when rolling down to a small final thickness, or when processing very hard material.

It will be noted from the diagram that the work rolls are arranged slightly off-centre. They are supported by the back-up rolls over the whole length of the barrel. Owing to the reduced diameter of the work rolls, higher pass reductions are possible with lower rolling pressures. These lower pressures increase the efficiency of operation, and by reducing the strains in the stand make it possible to keep closer tolerances.

Swiss Foreign Trade in First Half of 1956

In the first six months of this year, Swiss imports amounted to nearly 3,546 million francs, an increase of 458 millions (14·8 per cent) over the same period of last year. Exports totalled 2902 millions, an increase of 254 millions, or 9·6 per cent. As regards quantity, imports have increased by 11·6 per cent, and exports by 8 per cent. Among exports, the main sections in which increases took place were machinery, where a new high level was reached, watches, and instruments and apparatus. Other fields where progress was made are chemical and pharmaceutical products and heavy chemicals. Aniline dyes, however, have had a setback. As last year, most of the Swiss exports went to other European countries. The position in relation to Switzerland's principal trade partners is illustrated in the accompanying tables :

Swiss Exports in First Half of 1956

(Figures in brackets are those for the corresponding period last year)

	Millions of francs
Textile industry	404·8 (375·9)
Engineering products	645·1 (581·4)
Watches	531·9 (471·0)
Instruments	211·6 (190·2)
Pharmaceutical products	217·5 (200·2)
Heavy chemicals	88·1 (75·1)
Aniline dyes	130·3 (144·7)
Foodstuffs	167·1 (146·8)
Others	505·8 (463·0)
Total	2902·2 (2648·3)

Swiss Foreign Trade in First Half of 1956

	Imports (Millions of francs)	Exports (Millions of francs)
German Federal Republic	855	405
Austria	79	86
France	413	263
Italy	343	241
Belgium and Luxembourg	174	140
Netherlands	153	122
Great Britain	196	157
United States of America	444	322

Swedish Forestry Research Centre

A forestry museum and research centre is to be opened in Gävle, Sweden. The centre will be supplemented by an Arboretum containing all the trees and the most important bushes which exist in the country, set in their natural environment. This was announced at a congress of foresters recently held at Gävle ; at this meeting, estimates were reported giving the Swedish tree population as 80,000 million, of which 1000 million are said to be fully grown.

U.S. Earth Satellite Programme for the International Geophysical Year

BY OUR AMERICAN EDITOR

As an American contribution to the International Geophysical Year, the U.S. Department of Defence will launch several artificial satellites known as "Vanguard" vehicles. Present plans call for spheres at least 20in in diameter and weighing 21·5 lb, to be launched by means of three-stage rockets from Cape Canaveral, in Florida. The satellites will be used to perform various experiments during orbital flight.

THE present earth satellite programme of the United States is a part of the International Geophysical Year programme. During the period from July, 1957, to December, 1958, there will be a concerted effort on the part of most of the nations of the earth to gather data of geophysical interest. The scope of the programme covers most of the scientific disciplines, and among the more highly publicised aspects there are the Arctic and Antarctic expeditions, which will involve many nations, and the rocket experiments which will be made at several places for upper atmosphere observations. The international committee which is co-ordinating the I.G.Y. programme recommended in October, 1954, that a satellite programme would be of extreme value as part of the I.G.Y. activity. In July of last year, President Eisenhower announced that the United States would indeed establish a satellite as part of her contribution to the I.G.Y. Since then the Russians have announced that they also will establish a satellite.

The programme for the United States has been established by giving the Department of Defence the responsibility for putting the satellite on orbit. This, of course, is the largest engineering problem; it involves the application of large rocket techniques developed over the past ten years. The President has stated that each of the services will contribute to this effort, but the primary responsibility has been given to the U.S. Navy. The Naval Research Laboratory has set up what is now known as "Project Vanguard." The scientific part of the programme is being co-ordinated by the National Academy of Sciences, which is responsible for the whole I.G.Y. scientific work on the part of the United States. There has been established a U.S. National Committee which carries out the I.G.Y. programme through a series of technical panels, one of which is the Technical Panel on the Earth Satellite Programme.

Theoretical Considerations

The velocity required for a satellite to move in a circular orbit above the surface of the earth is obtained by equating the centrifugal force to the gravitational force. Thus, for an altitude of 300 miles it needs a velocity of just over 25,000ft per second. As the altitude increases the required velocity will decrease; however, the total energy required to take an object from the surface into the orbit will, of course, go up. The total energy, adding the potential and kinetic energies, is a fairly slowly varying function of altitude. At 300 miles it is about 11,000,000ft-lb per pound of mass of the object.

The exact height at which one might like to establish a satellite will be determined by the amount of energy available and, secondly, by the desired life of the satellite. The life is limited by the fact that the satellite is not moving in a perfect vacuum, and the residual trace of atmosphere at these altitudes will slow it down, so that the object will eventually lose energy to the extent that it will spiral into the earth and be burned up as it enters the dense atmosphere. An altitude of 300 miles is predicted to give a lifetime which will be measured in weeks or months. There is considerable uncertainty as to the actual density of the atmosphere at these altitudes, and so the prediction of lifetime is uncertain, but the best estimates say that at 300 miles it will be at least several weeks and may be as long as a year.

In order to place an object actually in an orbit it will be necessary to give it more energy than that required for a circular orbit. In the case of the "Vanguard" the orbit will become elliptical and, assuming that the object is launched from an altitude of 300 miles in a horizontal direction, the launching point will be the perigee of the ellipse. The altitude of the apogee will depend upon the magnitude of the excess velocity imparted to the object. The expectation is that the "Vanguard" satellite orbit will be an ellipse which is about 200 miles high at the closest approach and about 800 miles at the apogee. The period, for a circular orbit, can be calculated from the velocity and the radius of the orbit, and at the 300-mile altitude the satellite will require about ninety-four minutes to go around the earth. It is interesting to ask: At what altitude would the period become twenty-four hours? In this case the object would remain apparently at rest over the launching area. This turns out to be a height of about 5·6 times the earth's radius.

As a practical consideration, if one plans to launch such a satellite vehicle, one might just as well take advantage of the fact that the earth is rotating toward the east with a velocity which amounts to 1500ft per second at the equator. Therefore one would like to launch the object from the equator and towards the east. Fortunately, the United States has a long-range proving ground at the Patrick Air Force Base on the east coast of Florida with a firing line towards the east, and all the necessary facilities for launching. Firing directly east from this site would give an additional velocity due to the earth's rotation of about 1300ft per second. The launching direction finally selected will probably be inclined somewhat to the south of east so that the plane of the orbit will intersect the plane of the equator at an angle between 35 deg. and 40 deg.

Two problems have been encountered regarding the accuracy of the direction of launching. The first is the azimuth accuracy which will determine the plane of the orbit. The required accuracy will depend on the location of observing stations, but presumably an accuracy of a few degrees would be acceptable. The second problem is the elevation accuracy. This will determine the perigee altitude. If the launching is accurately horizontal the launching altitude is the perigee altitude. Any other launching angle will lower the perigee. If the direction deviates as much as 1·5 deg. the perigee will drop about 100 miles. This means, then, that the accuracy of launching must be somewhere of the order of 1 deg. Thus, to sum up, it is required to take the satellite object to an altitude of 300 miles and launch it with a velocity of 5 miles per second in a specified direction with an accuracy of about 1 deg.

Rocket Design

"Project Vanguard" will consist of a three-stage rocket, the first stage having some similarities to the "Viking" rocket, the second stage having some similarities to the "Aerobee" rocket, and the third stage being a solid propellant rocket. The shape of trajectory which will be flown is indicated in Fig. 1. The first stage will take the satellite up to about 40 miles and, with combustion complete, the first stage will drop off. At this time the velocity is about 5000ft per second. The second stage will take over and carry the satellite up to about 140 miles with a velocity of 16,000ft per second. At this time combustion is complete, but the second stage is left attached to the third stage, and together they will coast up to a 300-mile altitude. At the 300-mile altitude, when the object is pointing in the correct direction, the third stage is ignited and begins moving on its orbit. The second stage, of course, is separated and will drop back to earth, arriving at a point about 1000 or 2000 miles away from the launching site. At the end of burning of the third stage it will be necessary to separate the ball from the rocket, and this can be accomplished by a simple spring-ejection device.

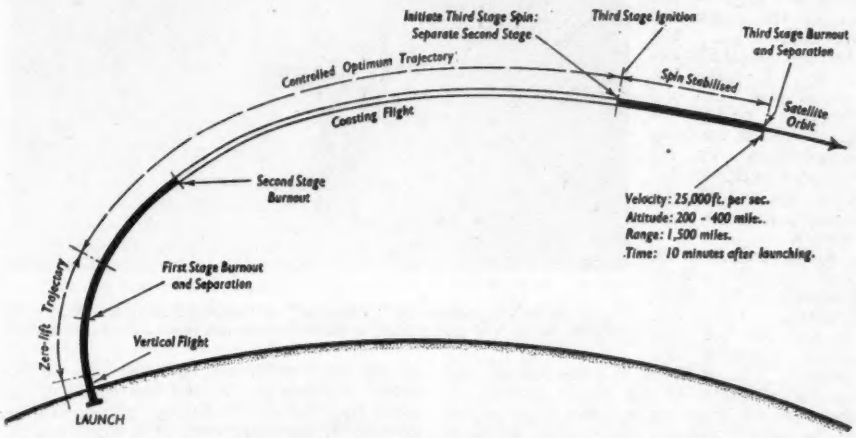


Fig. 1—Diagram showing preliminary launching trajectory of the "Vanguard" satellites

The problem of keeping the rocket on its trajectory is a very critical one. Guidance is obviously going to be necessary during the whole combustion process. It is proposed, however, that none of the rockets possess fins or any aerodynamic surfaces to guide them, but that since most of the flight has to be in a vacuum, it will be guided by swivelling the rocket motor in each of the first two stages. In the final stage, since there is a solid propellant motor, the simplest thing is just to give it a spin to maintain its orientation.

The first stage of the vehicle will be an improved "Viking" rocket. The motor, using liquid oxygen and a mixture of alcohol and petrol as propellants, will burn for about 140 seconds, at a thrust of about 27,000 lb. Mounted in gimbals, the thrust chamber of the rocket will be movable so that the direction of the thrust can be varied by as much as 5 deg. in any direction about the longitudinal axis. This will permit control of the rocket in both pitch and yaw. Roll will be controlled by small auxiliary jets. The second stage is similar to the "Aerobee" rocket. Its propellants will be nitric acid and unsymmetrical dimethyl-hydrazine fed to the motor from tanks pressurised with helium gas. As in the first stage rocket, the motor will be gimbal-mounted. It will be

necessary to control the second stage after burning during its coasting flight to the third stage launching point. This will be done with a complete array of small jet reactors. The third stage will be an unguided solid propellant rocket. It will be spun while in the second stage, separated when the second stage has reached orbital altitude and is properly oriented, and then ignited. The ideal, of course, would be to have the third stage moving exactly horizontally at the moment it ceases burning. At the end of third stage propulsion, the instrumentation vehicle and the third stage bottle will be parted by a device which will give them a separation velocity of a few feet per second. Both will then revolve about the earth as separate satellites.

The complete launching vehicle will be over 70ft long, 45in at its greatest diameter and will have a gross weight at take-off of about 11 tons. The Glenn L. Martin Company has the prime contract for the "Vanguard" launching vehicle. The General Electric Company will supply the motor for the first stage. The Aerojet General Corporation will make the second stage. The solid propellant rockets for the third stage are being manufactured by the Grand Central Rocket Company and the Allegheny Ballistics Laboratory.

Rising vertically at the start, the rocket will tilt gradually in the chosen direction of flight until at the end of first stage burning the missile will be at about 35 miles altitude and moving at roughly 45 deg. to the vertical. At this point the first stage separates from the rest of the vehicle, and the second stage ignites at once, carrying itself and the third stage onward toward orbital altitude. The second third-stage combination will continue to tilt more and more toward the horizontal as the flight progresses. Burn-out will occur at a height of about 140 miles, after which the combination will coast to an altitude of 300 miles at some 700 miles horizontal range from the launching point. During this coasting period, the second stage will be oriented properly for the firing of the third stage, and the third stage rocket will be spun to provide stability. At second stage zenith the third stage will separate and fire. Following burn-out of the third stage rocket, it is planned to cause the instrumented satellite and the third stage bottle to separate at a relative velocity of a few feet per second. The third stage bottle will, therefore, itself be a satellite, and it may be possible to make some useful comparative observations on both the principal satellite and this secondary one.

The guidance for achieving the trajectory described will be carried in the second stage of the "Vanguard" vehicle. As a result of the increasing tilt toward the horizontal called for in the guidance programme, each stage will contribute to the ultimate horizontal velocity of the satellite. In order, the first, second, and final stages will deliver something like 15, 32, and 50 per cent of the required 26,000ft per second. The remainder will be provided by the rotational velocity of the earth corresponding to the latitude of the launching point. In the early part of the flight, the satellite itself will be shielded from aerodynamic heating by a disposable nose-cone. During the second stage burning the shield will be discarded as soon as it is no longer needed to protect the satellite.

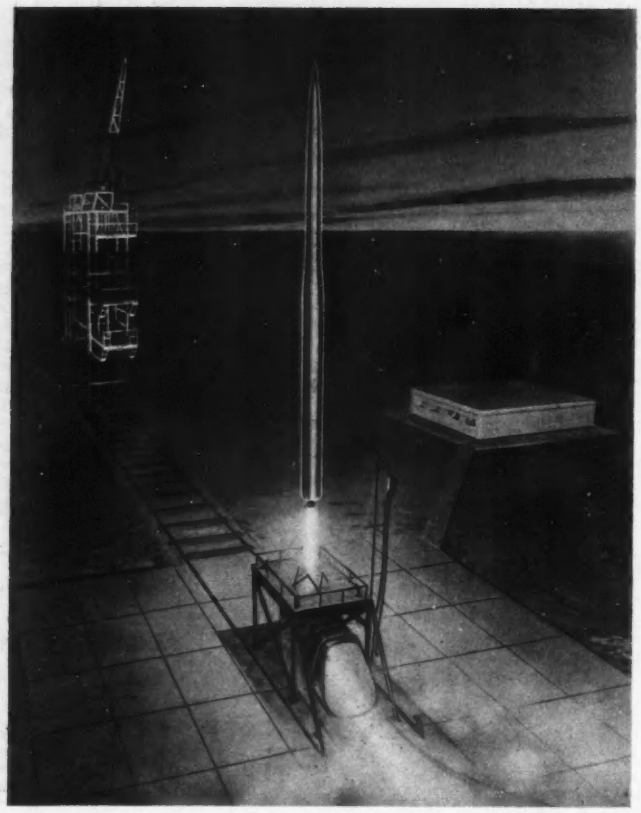


Fig. 2—Artist's impression of "Vanguard" rocket-propelled vehicle leaving its launching stand, with gantry crane in the background and observation house at right

Satellite Orbit

Supposing that the satellite is launched at an angle of about 40 deg. with the equator, the map reproduced in Fig. 3 indicates the regions of the earth which will be swept over by the orbit. As time goes on, all that region of the earth lying between ±40 deg. latitude will be covered by the trajectory. It is interesting to consider the question of visual observations. At any given point, the time that the object is above the horizon is very short. If it goes over the zenith, the time will be of the order of 9 minutes from horizon to horizon, and it will rise in the west and set in the east. There will be no difficulty in distinguishing it from the other heavenly bodies.

The "Vanguard" satellites will be tracked both optically and by wireless. The optical method has the advantage that it does not require any active equipment in the satellite, although an appropriate light source in the vehicle would greatly facilitate its observation. Without such a light source, the satellite will be observable only when illuminated by the sun, and only when the sky background is sufficiently dark; i.e. only when it is present in the vicinity of the observer about an hour after sunset or before sunrise. The optical observing programme for the International Geophysical Year is being organised for the U.S. National Committee by the Smithsonian Astrophysical Observatory. It is planned to set up special stations, to solicit wide national and international participation, and to encourage and help organise amateur astronomers to observe the satellite. In this way it is hoped that the orbital belt will be well covered. By including photographic methods in the plans, it is expected to obtain data on angular positions accurate to within a few seconds of arc.

Wireless interferometry will be used by the Naval Research Laboratory to track the satellite by wireless. A lightweight, crystal-controlled transmitter in the satellite will put out between 10 and 50 milliwatts at a frequency of 108 Mc/s. At the ground the signal will be received by two aerials 500ft apart, and compared in phase. The phase difference will depend upon the difference in path-length from the satellite to the two aerials, and will provide a measure of the angle between the ray path and the direction of the aerial baseline. The long baseline provides accuracy but gives several possible answers, thus introducing ambiguity into the system. The ambiguity can be partially removed by using a third aerial between the first two but only 50ft from and paired with one of them. The two aerials 50ft apart will provide a second, coarser, measurement of the angle between the ray path and the aerial baseline. This coarse measurement can be used over a limited range of angles to select the proper value from the choice of more accurately determined angles. By inserting still a fourth aerial on the baseline only 7·5ft from and paired with the third aerial, ambiguity can be further reduced. Two such aerial systems with baselines crossing at right angles will be used to give the two direction angles needed to determine uniquely the direction in space from the observing site to the satellite.

The wireless tracking system described has been given the name Minitrack. It is planned to set up a line of Minitrack stations along roughly a single meridian, spaced so that their aerial patterns will cover the latitude range from the northernmost possible excursion of the satellite to the southernmost. In addition an initial acquisition station will be placed downrange from the launching area, situated so that the satellite can be observed immediately after the end of third stage burning. It is expected that after half a dozen Minitrack readings on the satellite it will be possible to put out orbital information good enough to ensure that the optical stations can acquire the satellite for their observations. There are plans to publish a description of a simplified Minitrack ground station which wireless amateur groups may be able to set up. With the participation of such groups the amount of wireless position data can be greatly increased.

There will be computational centres organised to handle the tracking data as they come in from the field stations. The U.S. Naval Research Laboratory will have such a centre for the

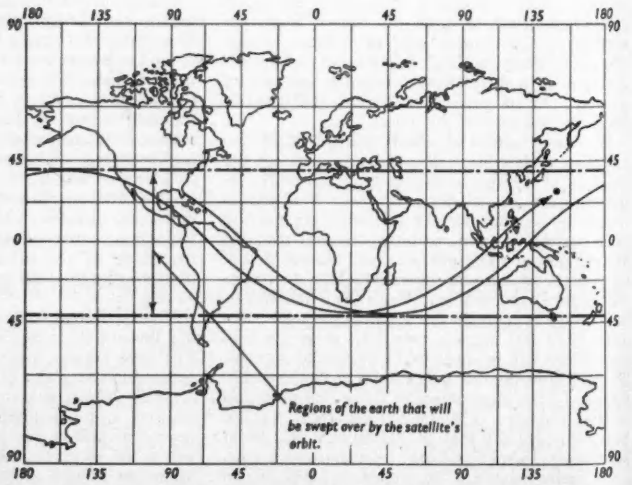


Fig. 3—Anticipated orbit of the American "Vanguard" earth satellites

Minitrack programme. Here the first task will be that of turning out ephemerides based on the early wireless tracking information. These data will be fed from the Minitrack stations to the computing centre where they should arrive within a quarter to a half an hour after being obtained. After processing, the resulting ephemerides will be published and distributed widely so that optical observers can acquire the satellite. Later on, the Minitrack computing centre will use Minitrack and optical data to turn out the most accurate description which those data permit of the actual path of the satellite during its history. The Smithsonian Astrophysical Observatory is planning a similar computational programme to be associated with the optical tracking of the satellite. An important ultimate output of this computational programme will be geodetic results and atmospheric densities at orbital altitudes. The two computational programmes are being closely co-ordinated. There will be arrangements for rapid communications and interchange of information between the two centres. On the international side, the widespread connections of the Harvard Observatory should be highly useful in disseminating the orbital information as it becomes available.

Data telemetered from the satellite will go via the Minitrack r.f. link. Present plans are to turn on the telemetering circuits as the satellite approaches a ground station. This can be done with a signal from a ground transmitter to a miniature receiver in the satellite. During telemetering operations the Minitrack oscillator will be switched from the low power Minitrack oscillator to a 0·5W transmitter modulated by the telemetering signal. To maintain the integrity of the tracking operation, this modulation will not be permitted to exceed 60 per cent. After a fixed period of perhaps half a minute, a suitable device in the satellite will de-energise the telemetering circuits and switch the antenna back to the low power oscillator.

Orbital Measurements

Supposing that a precise orbit of the satellite is obtained, the question one might ask is : What kind of information can be deduced from such knowledge, and is it possible to obtain useful data from external measurements ? Four useful areas of investigation are : air density along the path ; variations in the shape of the earth ; anomalies in the distribution of matter within the earth ; and precise knowledge of the relative location of points on the earth's surface. There is considerable interest in the density of the atmosphere at these altitudes. It is of the general order of magnitude of 10^{-15} grammes per cubic centimetre, which by all ordinary standards is an excellent vacuum ; but from the astrophysical point of view, one would like to know just how density does vary with altitude in this region. This small density of perhaps 10^{-15} grammes per cubic centimetre will exert a small drag on the object. If the drag force is assumed to be proportional to the frontal area, the square of the velocity and the density, then the loss of energy and of velocity per revolution can be determined. With regard to the shape of the earth, we know that in a broad sense the earth is an oblate spheroid. This fact will cause the plane of the orbit to precess around the axis of the earth with a period of about fifty days. Again, if one has the precise orbit, one can calculate back to obtain information on the actual shape of the earth.

Finally, if one considers the problem of locating an island some distance off the coast of a continental mass, this can be done by measuring the latitude and longitude of the two points. But in order to do this, one has to use the local vertical, and one wonders if the local vertical is indeed the direction to the centre of the earth. With a satellite it becomes possible to put an observing site both on the island and on the continental mass to observe the satellite, and then by simple trigonometry to obtain the separation between the two. Likewise, if the orbital parameters are known precisely, the path of the satellite can be used to survey the observing station. Thus it appears that, even with data from the satellite restricted to observations from the ground, a wealth of useful information will be obtained, provided only that the object can be tracked visually.

Satellite Experiments

At the present time the Technical Panel on the Earth Satellite Programme of the U.S. National Committee for the I.G.Y. is considering numerous suggestions and proposals for satellite experiments. They include geodetic studies ; determination of upper air densities ; measurements of dust and micrometeorites in space and their erosive effects upon the surface of a satellite ; observation and measurement of the sun's radiation in the ultra-violet and X-ray wavelengths, in particular in the Lyman alpha region ; determination of the amount of hydrogen in interplanetary space by means of Lyman alpha observations ; measurement of the earth's albedo ; magnetic field measurements ; ionospheric studies ; and cosmic ray observations. The Panel will select from the list a number of experiments to be performed in the I.G.Y. satellites and will assign an order of priority to the chosen experiments.

With regard to internal measurements, the temperature of the satellite object itself will be determined by the radiation balance—the radiation falling on the object and the re-radiation from the object. Knowing something about the infra-red characteristics of the surface of the satellite, and knowing what we do about the solar radiation, one can hope to establish a balance that will keep the instrumentation of the satellite at a fairly uniform temperature. However, there will be fluctuations as it goes around the earth and behind the shadow of the earth. The temperature will not go very low during this period because of re-radiation from the earth, although there is considerable question as to just what this re-radiation from the earth actually consists of. A second internal measurement could be a pressure measurement. From the point of view of the instrumentation which is carried in the satellite, it will almost certainly be desirable to make it pressure-tight. If the satellite is bombarded by small meteorites, these will make holes through the skin and the internal pressure will be lost. By observing the pressure, as a function of time, one can obtain information on the probability of collision with the small meteorites.

These first two measurements will be made on the first satellite objects, for instrumentation purposes, if for nothing else, because future satellites with more elaborate instrumentation aboard will require information about the environmental conditions on the satellite. Another class of measurement is that of radiation. All the radiation observed at the surface of the earth has been filtered through the atmosphere and absorbed by the atmosphere. The atmosphere is actually opaque to radiations of many wavelengths. Now, by balloon measurements and by high-altitude sounding rocket measurements, direct measurements of the radiation at high altitudes have been obtained, but these earlier measurements are limited because of the fact that the measurement is made at one particular point in space and one particular time. In the case of a rocket the time spent outside the atmosphere is measured in seconds. Balloons stay up for longer periods of time, but will not reach high altitudes. The satellite, on the other hand, is up for an indefinitely long time and at higher altitudes than have been attained before.

To-day there is a great deal of interest in the variation of cosmic rays as a function of latitude, longitude and time. The satellite is particularly useful for measuring primary cosmic radiation because of the fact that it sweeps over large areas of the earth's surface in a short period of time. From the cosmic ray point of view one would prefer to have the orbit going over the poles rather than in an equatorial direction, but the inclined orbit which is planned should provide exceedingly interesting data.

The Lyman alpha radiation from the sun lies in the far ultra-violet with a wavelength of about 1200 Ångstroms. There is now considerable interest in just what the intensity of this radiation actually is. Measurements have been made from sounding rockets ; however, the sounding rocket measurements suffer from the disadvantage that they make a single observation on the condition of the sun as it happens to exist at the time. It is believed that the Lyman alpha intensity from the sun varies over very wide ranges and one would like very much to observe the changes in this radiation as the sun goes through some sort of disturbed condition. Here again, the continued series of observations possible from the satellite over a period of weeks provides an opportunity for finding the sun in a disturbed condition and therefore obtaining the required information.

Finally, an interesting experiment will be a further investigation of meteoritic dust or micrometeorites. It is feasible that the surface of the satellite may be eroded by bombardment with cosmic dust. One proposal is that the satellite should start out with a polished surface which has a certain apparent brightness. As time goes on that brightness may change due to a change in the condition of the surface brought about by meteoric dust. Another proposal has been made to coat the surface with a certain amount of radioactive material, and by measurements of changes in the radioactivity one could determine how much has been worn off. Before the first satellite is set up, many more experiments may be under consideration.

New Construction Programme of the Bureau of Reclamation

A 174 million dollar construction programme for the new fiscal year beginning July 1st has been initiated by the U.S. Bureau of Reclamation with funds made available when President Eisenhower signed the public works appropriation bill recently. In addition to various important new starts—including aspects of the Colorado River Storage Project—construction will be active throughout sixteen Western States on sixty projects already under way. Of the available funds, 28,012,000 dollars are earmarked for ten new starts as follows : Ventura Project, California, 6,400,000 dollars ; Washita Project, Oklahoma, 500,000 dollars ; Talent Division Rogue River Project, Oregon, 2,400,000 dollars ; Collbran Project, Colorado, 1,000,000 dollars ; Colorado River Storage Project, 13,000,000 dollars, with three new starts this year, including 9,325,000 dollars for Glen Canyon dam in Arizona, 1,300,000 dollars for Flaming Gorge dam in Utah, 800,000 dollars for Navajo dam in New Mexico, and 1,575,000 dollars for preliminary work on the participating irrigation units ; remaining power facilities on the Colorado-Big Thompson Project, Colorado, 433,000 dollars ; power stations of the Weber Basin Project, Utah, 1,299,000 dollars ; and Fremont power station, Glendo Unit, Missouri River Basin Project, Wyoming, 2,980,000 dollars.

A total of 57,900kW of generating capacity is involved in new hydro-electric plant to be placed under construction this year. In addition, the Glen Canyon and Flaming Gorge dams of the Colorado River Storage Project will have an ultimate capacity of 1,000,000kW, although work will not be started on the power stations at these dams during this fiscal year. The bulk of the water distribution facilities to be completed this year will add a supplemental supply of water to existing irrigated lands. The Palisades dam on the Snake River will start storing water this year to serve 650,000 acres of irrigated land in the Snake River Valley in Idaho with a supplemental supply. The rehabilitation of the Middle Rio Grande Project in New Mexico as a water conservation measure will enhance the supply to the 45,000 acres of that project, and about 120,000 acres of dry farmland will have water available to start irrigated farming.

This fiscal year will also see the installation of 85,500kW of hydro-electric generating capacity. This capacity is all situated at the Palisades dam on the Snake River near the Idaho-Wyoming border. This largest earthfill dam ever constructed by the Bureau of Reclamation is nearing completion and power will go on the line from the first of its four 28·5MW capacity generators in December with storage capacity of 1,400,000 acre-feet. Palisades will provide a supplemental supply for 650,000 acres of land.

Personal and Business

Appointments

COL. F. T. DAVIES has been appointed to the board of the Pressed Steel Company, Ltd.

MR. E. STANFORD has been appointed deputy chairman of the Crawley Development Corporation.

MULLARD, Ltd., announces the appointments to the board of Dr. F. E. Jones and Dr. J. D. Stephenson.

MR. JAMES F. WIDMAN has been appointed to the board of Union Carbide, Ltd., 103, Mount Street, London, W.1.

MR. GORDON FRENCH has been appointed deputy to Mr. Norman G. Widger, publicity manager of G. and J. Weir, Ltd.

MR. J. J. CUMMING, M.Eng., A.M.I.C.E., has been appointed assistant engineer (new works) London Midland Region, British Railways.

MR. B. W. KERRIGAN has been appointed secretary of the Institution of Mining and Metallurgy, and will take up his duties at the beginning of September, 1956.

MR. FREDERICK DORRIEN HUCKLESBY has been appointed superintendent of the process development section of the sales technical service department, British Oxygen Company, Ltd., Cricklewood.

BRISTOL AIRCRAFT, Ltd., announces that its board has been joined by Mr. T. B. Pritchard, hitherto chief accountant, as financial director, and Mr. G. E. Knight, hitherto secretary, as commercial director.

MARCONI'S WIRELESS TELEGRAPH COMPANY, Ltd., announces the appointment of Mr. J. P. Wykes to the post of manager, Maritime Division, and Mr. B.G.H. Rowley to that of assistant commercial manager.

MR. C. J. MOLE, A.M.I.E.E., formerly with the English Electric Company, has taken up an appointment as consultant with Peregrine and Partners of The Manor House, Royston, Herts, and 9, Ovington Gardens, London, S.W.3.

FIELDEN ELECTRONICS, Ltd., of Wythenshawe, Manchester, announces the appointment of Mr. G. Ensor, B.Sc., A.M.I.E.E., a director of the company, to general manager, and that of Mr. Victor Thomas to general sales manager.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., and the Automatic Telephone and Electric Company, Ltd., announce that Sir Archibald Gill, B.Sc.(Eng.), M.I.E.E., F.I.R.E., has joined British Telecommunications Research, Ltd., as director and general manager.

THE GENERAL ELECTRIC COMPANY, Ltd., announces the appointment of Mr. C. J. O. Garrard, M.Sc., M.I.E.E., as manager of the company's switchgear and transformer works group at Witton. Mr. J. S. Cliff, M.I.E.E., has been appointed manager of the switchgear works at Witton.

MR. DONALD A. BENNETT has been appointed general manager of the International Synthetic Rubber Company, which has been formed by Dunlop in partnership with the Goodyear, Firestone and Michelin companies in Britain to make general purpose synthetic rubber on a large scale.

KEITH BLACKMAN, Ltd., announces that the following executives have been appointed to serve as directors: Mr. C. J. Atkins, sales director; Mr. F. W. Goodge, contracts director; and Mr. S. Hudson, director and London works manager. At the same time Mr. A. H. Woodley was appointed sales manager.

THE CATERPILLAR TRACTOR COMPANY, Ltd., Desford, Leicester, announces the appointment of Mr. Denis H. Gilliver to the position of secretary of the company, and Mr. Graham W. Almrott as manager of the company's operations at Desford, Leicester. Mr. Almrott will be succeeded as merchandise manager by Mr. Thomas V. J. Armstrong.

THE BRITISH INSTITUTE OF MANAGEMENT announces the election as its new chairman of Mr. H. Wilmot, C.B.E., chairman and managing director of Beyer, Peacock and Co., Ltd. Mr. Wilmot succeeds Mr H. F. Spencer who retires after the customary period of two years. In recognition if his services Mr. Spencer has been elected a life vice-president of the Institute.

MR. F. W. MARTIN has been appointed deputy chairman of Tube Products, Ltd., of Oldbury. On taking up this appointment, Mr. Martin has relinquished his appointment as joint managing director of Tube Products, Ltd., and has been succeeded in this post by Mr. E. D. E. Andrewes. Mr. Andrewes has relinquished his joint managing directorship of Accles and Pollock, Ltd., of Oldbury, but remains a director of that company.

W. T. HENLEY'S TELEGRAPH WORKS COMPANY, Ltd., announces the following appointments: Mr. W. L. Willey to be manager of the firm's Birmingham branch as from October 1, 1956, in succession to Mr. F. C. Horsford, who will be retiring for health reasons; Mr. R. K. Palmer will succeed Mr. Willey as the Hull branch manager and Mr. S. W. Featherstone, the chief clerk at the Hull branch, will be the branch representative. Mr. W. J. Combellack has been appointed manager of the firm's Leicester branch, Mr. J. S. George, Cardiff branch representative, and Mr. R. V. Maller, Colchester branch representative; Mr. R. C. Jones, who, for many years, has been the firm's senior representative for electrical distribution equipment in the Greater London area, has been appointed to take over, in addition to his present duties, those previously carried out by the late Mr. T. D. Ratcliffe.

Business Announcements

DETUNERS, Ltd., has moved to larger premises at 58, Highgate West Hill, London, N.6. (telephone: Fitzroy 1221 (5 lines)).

HORACE W. CULLUM AND CO., Ltd., has moved to larger and modernised premises at 58, Highgate West Hill, London, N.6 (telephone, Fitzroy 1221 (5 lines)).

THE HOFFMANN MANUFACTURING COMPANY, Ltd., Chelmsford, Essex, has moved its stockroom from 19, Bury Place to new and larger premises at 19, Store Street, London, W.C.1.

DALLOW LAMBERT AND CO., Ltd., Thurmaston, Leicester, has moved its London office to more commodious and conveniently situated premises at 6, Stratton Street, London, W.1 (telephone: Grosvenor 4766, telegrams: "Deduster Wesphone" London).

ELLIOTT BROTHERS (LONDON), Ltd., is to manufacture and market Giannini shaft-rotation "digitisers" under a recently announced agreement with Giannini, Ltd., 45, Gresham Street, London, E.C.2 (the British affiliate of the American company G.M. Giannini and Co., Inc., of Pasadena, California).

SHEEPBRIDGE ENGINEERING, Ltd., announces that agreement has been entered into with Gebr. Eickhoff Maschinenfabrik u. Eisengiesserei, m.b.H., Bochum, Germany, for the manufacture at the Chesterfield works of Sheepbridge Equipment, Ltd., of components for Eickhoff steel plate mining conveyors. Sales of the conveyors will continue to be handled by W. Stanley Jones (Engineers), Ltd., of Altrincham, Cheshire and E. Wheatley, Ltd., of Sheffield.

THE BRITISH TRANSPORT COMMISSION has reorganised the administration of its Humber ports of Hull, Grimsby and Immingham and Goole under three separate managements groups, each being responsible directly to the management board for British Transport Docks. Hull Docks are now under the control of a chief docks manager, Mr. H. L. Hopkins, C.I.E., O.B.E., Grimsby and Immingham remaining under the control of the port master, Mr. H. M. Mitton; and Goole under the dock manager, Mr. R. Buttery.

VICKERS, Ltd., acquired in May last through its subsidiary, Vickers Australia Pty., Ltd., a 75 per cent interest in Hoskins Engineering and Foundry Pty., Ltd., of Perth, Western Australia. The name of the company has now been changed to Vickers Hoskins Pty., Ltd., and the board has been reconstituted as follows: Mr. A. R. L. Wiltshire, C.M.G., D.S.O., M.C., V.D. (chairman), Mr. G. M. Bunning, Mr. T. H. Ineson (managing director), Mr. P. H. Muirhead, C.B.E. (alternate Mr. A. Campbell), Mr. E. Sandover, Mr. G. N. Stuart and Dr. H. M. Trethowan.

THE CATERPILLAR TRACTOR COMPANY, Ltd., has purchased the factory, plant and stock of the Birtley Company, Ltd., Birtley, County Durham. The Birtley Company has, for the past nine years, been manufacturing earthmoving equipment under licence from the American parent of British Caterpillar and this manufacture will be continued and expanded. Col. R. T. Edwards, managing director of the Birtley Company, will continue in charge as manager of the Caterpillar operations at Birtley and has become a member of the board of directors of Caterpillar, Tractor Company, Ltd.

ASSOCIATED BRITISH ENGINEERING, Ltd., announces that as from September 1, 1956, its London address will be: 37-41, Bedford, Row, London, W.C.1 (telephone: Holborn 6881/5). This company also announces the formation of a new subsidiary company, Associated British Engineering (Canada), Ltd., with head office in Montreal, P.Q. This Canadian subsidiary has in turn acquired the Hepworth Lachine Engineering Company, also of Montreal. Mr. Lawrence Robson, chairman of Associated British Engineering, Ltd., becomes chairman of the two Canadian subsidiaries. Mr. R. G. Fuller, resident in Montreal, has been appointed managing director of Associated British Engineering (Canada) Ltd., and a director of Hepworth Lachine Engineering Company.

THE BRITISH THOMSON-HOUSTON COMPANY, Ltd., announces that, following the withdrawal of the Rank Group interests from Sound Equipment, Ltd., that company has become a wholly owned subsidiary of the British Thomson-Houston Company, Ltd., and its name will be changed to B.T.H. Sound Equipment, Ltd. Mr. J. Arthur Rank, Mr. John H. Davis, Mr. A. S. Kettle, Mr. E. S. Little, Mr. J. Metcalfe and Mr. W. W. Vinsen have retired from the board to which the following new appointments have been made: Mr. W. S. Steel (chairman), Mr. E. V. Bowers (managing director), Mr. E. G. Crossling, Mr. G. S. C. Lucas and Mr. V. M. Roberts. The company will continue to supply and service cinema equipment and will also broaden the scope of its activities in this field.

Contracts

THE NATIONAL GAS AND OIL ENGINE COMPANY, Ltd., Ashton-under-Lyne, has received a contract from the Auckland Metropolitan Drainage Board, for diesel generating plant for the Manukau sewage purification works, Auckland. The firm will supply four "B2AP8" dual-fuel engines, running at 333 r.p.m., and each developing 1040 b.h.p. on diesel fuel and 1000 b.h.p. on sewage gas. Each engine will be directly coupled to a Brush 400/410V, three-phase, 50 c/s alternator.

MARCONI INSTRUMENTS, Ltd., is to supply two 250kV industrial X-ray equipments to the Ministry of Supply, for installation in the Royal Ordnance Factory at Bishopton, near Glasgow. Each equipment comprises a constant-potential high-tension generator, a control unit, an oil cooler, and an oil-cooled shockproof tube head. The voltage range, 30kV to 250kV, is sufficient, for example, to penetrate steel of up to 3½in in thickness. The constant-potential generator enables the whole of the high-voltage energy to contribute to X-ray generation, which allows exposure times to be greatly shortened.

G. AND J. WEIR, Ltd., Glasgow, has received an order for a fifth set of sea-water evaporating and distilling equipment for the Island of Aruba, Netherlands Antilles. It is in addition to the £1,250,000 order received last February for four sextuple-effect plants to produce 8000 tons of fresh water a day in the island. It was later decided by the executive council of the island to increase the capacity of the plant to 10,000 tons a day, bringing the original order up to nearly £1,500,000. Production is well up to time on the original order, which is due for completion in 1957.

RICHARDSONS WESTGARTH (HARTLEPOOL), Ltd., announces that a contract has been received from the Pakistan Industrial Development Corporation for the supply of two gas-turbine-driven generating sets for Multan, Pakistan. Each of these units will be of Richardsons Westgarth-Brown Boveri single-shaft, open-cycle design, without regenerative heating, and will have an output of 5700kW with an ambient temperature of 104 deg. Fah. This output is increased to nearly 7000kW, when the air temperature drops to approximately 65 deg. Fah. The sets will use either natural gas or heavy fuel oil and both the gas turbines and alternators will be built at Hartlepool.

THE FRASER AND CHALMERS ENGINEERING WORKS of The General Electric Company, Ltd., has received a contract from the National Coal Board for a comprehensive surface handling plant for installation at Lea Hall Colliery, now in course of construction in the Cannock Chase area of the West Midlands Division. The conveying equipment will be designed initially to handle coal and dirt from both shafts at a rated capacity of 600 tons an hour, carrying the material forward through feeders, screens and crushers, whence the coal will be delivered to blending bunkers and the dirt to surge bunkers for disposal. Provision is also made in the system for a future coal preparation plant which may also treat coal imported from other pits. A side-discharge, 35-ton-capacity wagon tippler will feed imported coal into the conveying system for delivery to the blending bunkers, where, together with output from Lea Hall Colliery, it will be discharged into a receiving hopper to supply the adjacent Rugeley generating station of the Central Electricity Authority. The contract is valued at approximately £250,000.

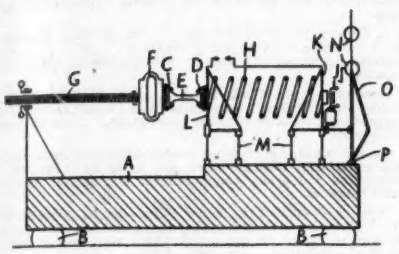
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

MEASURING APPLIANCES

753,286. July 2, 1954.—DYNAMIC MATERIAL TEST MACHINE, W. and T. Avery, Ltd., Soho Foundry, Birmingham 40. (*Communicated by Carl Schenck Maschinenfabrik G.m.b.H., of Landwehrstrasse, 55, Dormstadt, Germany.*)

The drawing illustrates the basic idea underlying the invention by means of a long-duration dynamic test machine incorporating a device according to the invention. The machine has a heavy bed *A* mounted on elastic legs *B*, with a pair of chuck heads *C* and *D* for the test piece *E*. A dynamometer *F*, which can be axially adjusted by means of a threaded helical spindle *G*, is secured to the head *C*, and a helical spring *H* which transfers variable loads on to the test piece is fixed at one end of the chuck end *D*. The excitement is driven from a motor-driven rotating



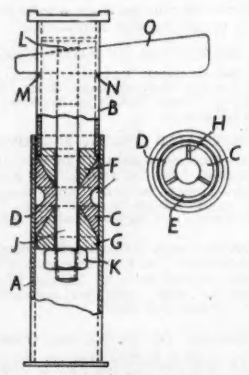
No. 753,286

unbalanced mass *J* to the other end of the spring. The exciting spring is gripped between two shields *K* and *L*, which are mounted on several elastic links *M*. The auxiliary mass *N* is coupled to the shield *K* by means of the ratio changing lever *O*. The lever fulcrum *P* lies on the bed of the machine. The period of the excited system is adjusted by sliding the mass *N* along the lever *O* to an alternate position according to requirements. The mass *N* may be replaced by a smaller or larger mass to admit of further variation of the period of oscillation. The invention can also be applied to test machines equipped with a pre-load spring in addition to the oscillating spring, as described in the prior specification No. 721,603.—*July* 18, 1956.

MINING ENGINEERING

753,358. January 15, 1954.—PIT PROPS, Heinrich Steinmann, trading as Westdeutsche Metallwarenfabrik Steinmann, 2 Nicolaistrasse, Wattenscheid, Germany.

The invention relates to yieldable pit props constructed of steel, light metal or the like, and comprising upper and lower prop portions, and includes improved expander arrangements. The pit prop shown in the drawing comprises a lower portion *A* and an upper portion *B* which rests on an expander completely enclosed by the lower portion. This expander comprises three gripping elements *C*,



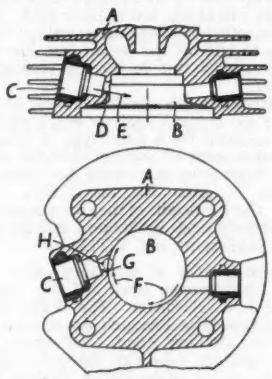
No. 753,358

D and *E*, which are segments of an axially apertured cylinder formed with similar symmetrical conical recesses, the apices of the cones being directed towards each other. Each element covers, in horizontal section, a segment extending over substantially one-third of the inner periphery of the lower prop portion. The upper and lower conical recesses in the elements accommodate correspondingly shaped spreader members *F* and *G*. Between adjacent gripping members there is provided a clearance *H* which permits the expander in the contracted condition to be introduced into the lower prop. Through central passages in the two conical members *F* and *G* there extends a rod *J* on to the lower end of which is screwed a nut *K* which carries the lower spreader member *G* and, above it, the entire expander. The upper bearing surface for the parts of the expander is constituted by the lower end of the upper prop portion *B*. The rod *J* extends through to the top of the upper prop and at this point there is a slot having an inclined upper bounding surface *L*. Level with this slot there are provided in the wall of the upper prop oppositely disposed slots *M* and *N*. By driving in a wedge *O* through the slots the rod is lifted and the expander members are accordingly urged together to expand the gripping elements against the wall of the lower prop. The pressure exerted against the wall can be regulated by the extent to which the wedge is driven in. Improvement of the frictional engagement of the expander gripping elements and the inner face of the lower prop portion can be obtained by fitting friction linings.—A modified form of construction is also shown in the specification. —*July* 25, 1956.

INTERNAL COMBUSTION ENGINES

753,385. April 12, 1954.—IMPROVEMENTS IN INJECTION PROCESSES, Andreas Stihl, 169 Badstrasse, Waiblingen-Neustadt, Germany. (*Inventors: Andreas Stihl and Siegfried Warth.*)

According to the invention, carbonisation in internal combustion engines is avoided by means of a slot formed in the mouth of the injection passage, in that side of the passage which is first met by the swirling air after it has travelled around the combustion chamber. A subsidiary turbulence is set up



No. 753,385

at that point which causes the air to pick up the fuel particles and thus prevents the deposit of fuel residues, and the nozzle is kept clean. As shown in the drawing, the lower part of the cylinder head *A* in which is located the combustion chamber *B*, forming the upper part of the compression space *C*, is a bore into which an injection nozzle may be screwed, and *D* is the injection passage leading from the nozzle into the combustion chamber. The direction of injection is indicated by the arrow *E* and the arrows *F* indicate the direction of the swirling of the air compressed in the combustion chamber. At the rear side of the passage *D*, that is at the side to which the swirling stream first approaches after travelling around the chamber *B*, is a small milled slot *G* having a convex profile in its rear wall, and by which a current swirl, shown by the arrow *H*, is formed before the nozzle mouth, by means of which all fuel residues are carried along and the nozzle mouth is kept clean.—*July* 25, 1956.

METALLURGY

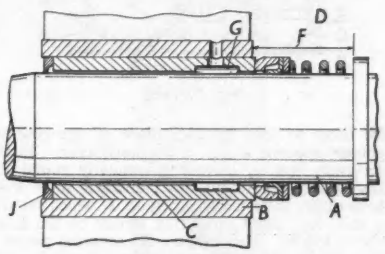
753,530. November 27, 1953.—IMPROVEMENTS IN TRAINS OF ROLLS, Schloemann Aktiengesellschaft, Steinstrasse 13, Düsseldorf, Germany.

The invention provides a multi-housing mill train, consisting of a continuous train of rolls, some housings of which have horizontal rolls while others have vertical rolls, and which can be used not only for the single-line rolling of billets, section bars and round material, but also for the rolling of flat material and for the multi-line rolling of sectional and round material. The arrangement is characterised by the feature that at some of the housing positions, such as at every other housing position, driving means both for horizontally and for vertically arranged rolls are provided, in which the motor, and some further driving elements, especially the first toothed-wheel transmission, are common to the drives of both the horizontal and the vertical rolls. Means for the optional accommodation of roll housings or sets of rolls with horizontally or vertically arranged rolls are also provided, as well as means for the optional accommodation of roll housings or sets of rolls with horizontally or vertically arranged rolls. The sole plates for the roll housings are so constructed that housings with horizontal or with vertical rolls can be mounted upon them.—*July* 25, 1956.

POWER TRANSMISSION

753,440. December 13, 1954.—GLANDS FOR SUBMERGED DRIVING OR OTHER SHAFTS, Albert Theodore Auguste Gentilhomme, 11, Rue Brindejonc-des-Moulinais, Nantes, France.

The invention relates to glands for submerged driving or other shafts, when the shaft passes from a space which is open to the atmosphere into water or other liquid, having abrasive matter, such as sand or grit, and the invention is a modification of the prior Specification No. 592,364. The object of the invention is to reduce the wear on the gland brasses or sleeves, and on the shafts, which would normally



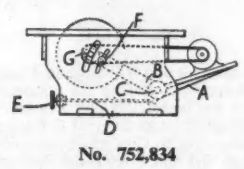
No. 753,440

arise in such circumstances from the access of abrasive particles to the clearance between the sleeve or brass and the shaft. The drawing shows a longitudinal section of a gland and propeller shaft of a ship, constructed in accordance with the invention. The end portion of the propeller shaft *A* passes through a gland mounted in a supporting bush *B* in the stern post structure of the ship. The gland comprises a brass or sleeve *C* having a clearance fit, one end of the sleeve communicating with the interior *D* of the ship, whilst the other end is under water. At the atmospheric end of the gland is provided known mechanical sealing means *F*, comprising an annular seal subject to the axial pressure of a coil spring, encircling shaft and bearing against a thrust collar on the shaft. Thus the seal is pressed tightly against the end of sleeve *C* and has a sealing ring making close contact with the shaft, to prevent any escape of air/oil mixture from the gland clearance. Close to the inner end of the sleeve is an internal annular groove *G*, to which air or gas carrying lubricating oil in fine suspension is supplied through radial bores in the supporting bush and sleeve respectively. The opposite, submerged end of the gland is unsealed and thus the oil bearing air or gas passes along the clearance space and escapes into the liquid in which that end of the gland is immersed. This end of the gland may be fitted with a diffuser ring *J* to convert the kinetic energy of the escaping oil-laden air or gas into pressure energy. The invention will also be of value for the protection of shafts and glands against liquids containing corrosives instead of abrasives.—*July* 25, 1956.

WOODWORKING MACHINERY

752,834. April 26, 1954.—CIRCULAR SAW BENCHES, Arthur Urquhart, 1023, Garrett Lane, London, S.W.17.

The invention relates to circular saw benches. As will be seen from the drawing, the saw bench is equipped with a double-armed lever *A* and *B*, which



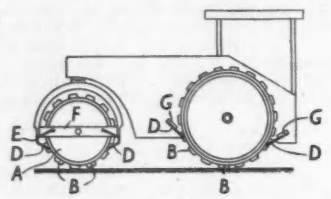
No. 752,834

is pivoted in the lower part of the frame at *C*. It carries the driving motor at one end and the saw spindle at the other. The motor is adjustable to alter the tension of the belt drive. Fine adjustment is provided by a rod *D*, attached to the lever below the fulcrum *C*, with a screwed portion and thrust collar where it passes through the frame, and terminates in a grooved handwheel *E*. A locking pin *F* is fitted on the upper part of the lever arm *B* and moves in a curved slot in the side of the frame. The saw spindle *G* is extended on the same side and projects through a curved slot, for the purpose of auxiliary drives.—*July* 18, 1956.

CIVIL ENGINEERING

753,666. January 11, 1954.—SOIL COMPRESSING ROLLERS, The Bayerische Berg-, Huetten-und Salzwerke Aktiengesellschaft, 16, Ludwigstrasse, Munich, Germany.

The invention provides a soil compressing roller in which a cylindrical rolling surface is provided with a series of spaced shallow curved projections arranged in rows running annularly around the surface. The front roller wheel *A* has cast-on shallow curved projections *B* of comparatively low, approximately tooth or cam-like form, which are mounted in rows arranged annularly around the periphery of the roller wheel adjacent to each other at spaced intervals. The projections of the adjacent rows are offset to



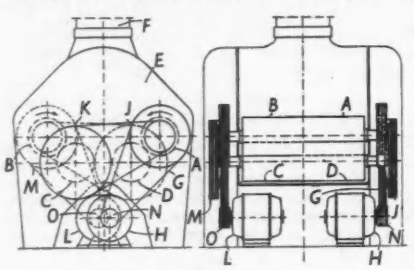
No. 753,666

each other so that the projections of one row are disposed opposite a gap in the next series. In the intervening spaces, extending annularly round the roller wheel, separating the individual rows from one another, there engage scrapers *D* which remove the soil, &c., taken up during service by the intermediate spaces. The scrapers are on cross pieces *E* which are hinged to the roller wheel frame *F*. The axis of rotation is so arranged that the scrapers are constantly pressed against the roller wheel by their own weight and, in particular, by the weight of their cross pieces. On the rear wheels the scrapers *D* are on displaceable iron supports *G*. The main difference of the rear compressing wheels relative to the front compressing wheel consists in the feature that the projections are not cast on the wheels themselves, but on sleeves or tyres which are secured by fixing pins or screws. If the rear wheels are to be equipped for roller work, the tyres are simply removed. Such tyres may also be provided for the front roller wheel. To convert a normal road roller into a compressing roller, it is only necessary to mount tyres on the front and rear wheels.—*July* 25, 1956.

ELECTRICAL ENGINEERING

744,611. January 21, 1953.—ELECTRICAL DRIVES FOR COUPLED FOUR-ROLLER MILLS, Adolf Buhler, of Sonnenhügel, Uzwil, and Rene Buhler, of Dreilinden, Uzwil, Canton of St. Gallen, Switzerland.

The invention relates to four-roller mills of the kind in which the rollers operate in two pairs. The electrical driving means comprises one or more power sources, and has two power take-offs, in invariable speed relation with each other for the two directly driven rollers. In the roller mill shown in the drawing,



No. 744,611

the grinding rollers *A* and *B* and *C* and *D* are mounted in the mill housing *E* having the connection *F* for the supply of the material to be ground. The fast roller *A* is driven through the belt *G* from the motor *H*, and the slow roller *C* of the other roller pair is driven through the belt *J* from the fast roller. The fast roller *B* is driven through belt *M* from the motor *L* and the slow roller *D* through the belt *K* from the fast roller *B*. The driving belt pulleys of the motors *H* and *L* are shown at *N* and *O*. Due to the entry of the material to be ground into the roller gap of each roller pair, the fast roller in each case tends to carry along the slow roller. On the other hand, however, the fast roller of one roller pair is connected by a belt to the slow roller of the other roller pair. In spite of the use of two separate motors the driving of the two roller pairs is in no way independent. Six modified arrangements of mill drives on the same principle are also included in the specification.—*February* 8, 1956.

Technical Reports

Design of Multi-Storey Steel Frame Buildings. By H. L. Holland, M.Sc., A.M.I.C.E. Association of Engineering and Shipbuilding Draughtsmen. Onslow Hall, Little Green, Richmond, Surrey. Price 3s. (members 1s. 6d.).—This report is in three parts. First, the general introduction to the subject, which includes notes on the various kinds of frames, design codes and specifications, and other general matters; second, an outline of simple design; and third, notes on fully rigid design.

A single-bay five-storey frame and a three-bay nine-storey frame are taken as examples in the second part. Connections, column details, and wind loading are discussed. The limitations of simple design, and the economies resulting from rigid design are discussed in Part III, and there is a slope-deflection analysis of a three-bay nine-storey rigid frame.

A.C. Network Analysers. Relation Between System and Analyser Quantities for Single-Frequency and Broad-Band Studies (Ref. V/T127). By A. P. N. Ford, Grad.I.E.E., and J. Miedzinski, B.Sc., A.M.I.E.E. The British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 10s. 6d., postage 4d.—Before an electric network can be studied on a network analyser, the original data on component values and operating levels must be converted to percentage form in which the analyser dials are marked. The final results of a study are usually converted back to the original form, but knowledge of the correlation between the system quantities and their representation on the analyser can assist the clients (i.e. the originators of the problem) in the interpretation of the analyser setting up diagrams and intermediate results. This is particularly important in case of more complicated problems, where a great deal of consultation must take place between the clients and the analyser staff. Furthermore, it may often be more economical for the clients themselves to convert the system data into the percentage form which can be directly represented on the analyser.

The treatment in this report is general and applicable to any a.c. network analyser which provides the facilities required for a given type of study. The range of adjustment of analyser elements and their frequency range must in addition be known. This information is given for the E.R.A. Network Analyser. Further details of the above equipment, its design, accuracy and limitations can be found in another E.R.A. report, Ref. V/T122.

Argon Arc Welding of Aluminium and its Alloys. Electrical Considerations (Ref. Z/T104). By L. H. Orton and J. C. Needham. The British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 15s., postage 4d.—This report has been prepared at the request of the British Welding Research Association Committee on Fusion Welding of Aluminium Alloys, to form one of a series of Technical Memoranda to be issued by that Association on the subject of the argon arc welding of aluminium and its alloys. It deals with the electrical characteristics of both the arc and power circuit necessary for adequate arc stability to promote high-quality welding. Conventional power plant, used, for example, for the metallic arc welding of mild steel, is not in itself suitable for argon arc welding, and additional electrical equipment or specially designed composite plant is required.

Stray Load Losses in Alternating Current Rotating Machinery. A Review of the State of the Art (Ref. Z/T102). By K. C. Mukherji, B.E. The British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 24s., postage 6d.—Stray load losses in alternating current rotating machines are defined as "the additional losses, wherever occurring, caused by the load current due to changes in flux distribution and to eddy currents." Some theoretical and a large volume of experimental work has been done in the past with regard to such losses in synchronous and induction machines, and yet the present knowledge of the phenomena is by no means adequate for design purposes. A brief account is given in this report of the more important investigations, with critical comments on the assumptions involved, the methods employed and the results achieved.

Water Sorption in Heat-Treated Polystyrene and Plasticised Polyvinyl Chloride (Ref. L/T344). By A. G. Day. The British Electrical and Allied Industries Research Association, Thorncroft Manor. Dorking Road, Leatherhead, Surrey. Price 10s. 6d., postage 4d.—Heat-treatment of polystyrene is shown to increase the sorption by about 20 per cent. Tests on polyvinyl chloride (P.V.C.) at low humidities show a good correlation with the Brunauer-Emmett-Teller adsorption theory and provide theoretical confirmation of one of the constants. Activation energies for P.V.C. are calculated and the temperature dependence of the isotherms is shown.

Reference Manual of German Machine Tools. By H. P. Gentzel. Coburg, Bavaria: Verlag Karl Ihl and Co. London: Publishing and Distributing Company, Ltd., 177, Regent Street, W.1. Price £2 7s. 6d.—This book is designed to provide a reference work for purchasers and importers of German machine tools in this country. It contains concise details of a wide selection of the machines and ancillary equipment of the latest designs available in Germany, together with a useful buyers' guide and list of manufacturers. The different types of machines are grouped in sections for easy reference and the information is well supplemented by illustrations.

Catalogues and Brochures

MERRYWEATHER AND SONS, Ltd., Greenwich High Road, London, S.E.10.—Publication No. 1801, dealing with marine fire-fighting and salvage equipment.

TEES SIDE BRIDGE AND ENGINEERING WORKS, Ltd., Middlesbrough.—Illustrated brochure giving details of a variety of products in which this company specialises.

BROOK MOTORS, Ltd., Empress Works, Huddersfield.—Leaflet giving details of a totally enclosed fan-cooled "Brook" motor and drip-proof motor built to British Standard dimensions.

N.G.N. ELECTRICAL, Ltd., Cawdor Street, Patricroft, Manchester.—Illustrative leaflet dealing with high-vacuum rotary piston pumps with gas ballast for pumping vapour containing gases.

G. HUNTER (LONDON), Ltd., 80, Fenchurch Street, London, E.C.3.—Catalogue describing "Mansaver" grabs used for handling equipment and built to meet the needs of the steel industry.

EXPANDITE, Ltd., Chase Road, London, N.W.10.—Folder dealing with "Mulseal" bitumen/rubber latex emulsion used for waterproofing all kinds of roofs, concrete gutters, tops of walls and copings.

GEORGE KENT, Ltd., Luton, Bedfordshire.—Publication No. 925, dealing with standard charts and scales for "Multelec" instruments and giving ranges suitable for general use in many industries.

MERITUS (BARNET), Ltd., Barnet, Herts.—Leaflet giving details of a high current neutral loop impedance and continuity tester designed to protect the user against shock when used on faulty electrical installations.

HUNTINGTON, HEBERLEIN AND CO., Ltd., Simon House, 28–29, Dover Street, London, W.1.—Brochure describing the Nichols Herreshoff furnace used for roasting, calcining and drying a wide range of ores and other materials.

THE MATTHEW HALL GROUP OF COMPANIES, Matthew Hall House, Dorset Square, London, N.W.1.—Catalogue describing and illustrating oil refinery, chemical and industrial engineering that this group of companies cover.

MARTONAIR, Ltd., Parkshot, Richmond, Surrey.—Leaflet dealing with a two-handed safety valve, intended for use on presses, guillotines and other machines where it is desirable that both hands are clear of the machine.

METWAY ELECTRICAL INDUSTRIES, Ltd., Metway Works, Canning Street, Kemp Town, Brighton, 7.—Catalogue No. OHN/32, illustrating and describing a range of conduit fittings and wiring accessories made by this company.

IMPERIAL CHEMICAL INDUSTRIES, Ltd., Imperial Chemical House, Millbank, London, S.W.1.—Brochure dealing with copper tubes for domestic water services, used mainly for the installation of hot and cold water systems in all types of buildings.

DORMAN AND SMITH, Ltd., Ordsal Electrical Works, Manchester, 5.—Consolidated price list giving form description of products, catalogue numbers and prices for the comprehensive range of standard electrical products made by this company.

BOULDER EQUIPMENT, Ltd., 18, High Street, Barnet, Herts.—Leaflets describing a pneumatic grouter for low to medium pressure grouting up to 90 lb per square inch. The small bulk of the "Boulder" grouter makes it suitable for underground use in tunnels, mine shafts and sewers.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Sept., 26th.—LONDON BRANCH: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Some Aspects of Transistor Progress," H. W. Loeb, 6.30 p.m.

INCORPORATED PLANT ENGINEERS

Mon., Sept. 3rd.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "Fan Engineering," 7.30 p.m.

Tues., Sept. 4th.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, Strand, W.C.2, "The Maintenance of Lancashire and Economic Boilers," J. H. Williams, 7 p.m.

Wed., Sept. 5th.—LEICESTER BRANCH: Bell Hotel, Leicester, "Planned Maintenance," A. F. R. Stedman, 6.30 p.m.

Mon., Sept. 10th.—DUNDEE BRANCH: Mathers Hotel, Dundee, "The Application of Work Study and Incentives to Maintenance," D. Gardiner, 7.30 p.m.

INSTITUTION OF NAVAL ARCHITECTS

Thurs., Oct. 11th.—Weir Lecture Hall, 10, Upper Belgrave Street, London, S.W.1, "Scale Effect Experiments on Victory Ships and Models," Part II, "Analysis of Wake Measurements on a Model Family and the Model Boat," D. C. Endert, Jr., J. D. van Manen, 4.45 p.m.

LIVERPOOL METALLURGICAL SOCIETY

Thurs., Oct. 11th.—The Temple, Dale Street, Liverpool, Presidential Address, W. Rose, 7 p.m.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE

Fri., Oct. 19th.—39, Elmbank Crescent, Glasgow, Symposium on the Application of Low-Alloy Steels for Welded Pressure Vessels, 10 a.m.